Important: If the response includes any change in the budget, the project sponsors must resubmit Part I of the proposal form with a revised budget section.

Responses and comments must be received at the Northwest Power Planning Council no later than 5 p.m., March 15, 2002. Please email responses and comments to kphillips@nwppc.org. Attachments should be in Microsoft Word or Excel (for tables).

ProjectID: 30007

An Acoustic Tracking Array for Studying Ocean Survival and Movements of Columbia River Salmon
Sponsor: Kintama Research Corporation
Province: Columbia Estuary
Subbasin: Columbia Estuary
FY03 Request: $2,930,535
5YR Estimate: $7,345,735
Short Description: Development of a skeleton acoustic array to demonstrate an approach to tracking movements of individual fish through the river and along the West Coast of North America. The project will initially be focused on salmon, but has much wider application.
Response Needed? Yes
ISRP Preliminary Recommendation and Comments:
A response is needed. This proposal continues to be technically innovative and the investigators have completed portions of the Innovative Project (#200008000) tasks. These results are presented and relevance to the FWP is well described.

We would like to thank the ISRP for their comments. We have found them to be carefully thought out and agree with the majority of them. Our response to each question is listed below.

"…the guidelines for the innovative project category require that sponsors complete the innovative study and submit a final report in order to be considered for additional funding. What is the status of completion of the final report?"
Submission of the final report will be possible once we complete a workshop in the Columbia River basin to disseminate the results from the contract. This is the one outstanding deliverable in the contract. We are currently working with a knowledgeable individual in the basin (Chuck Pevin) to identify the appropriate individuals to invite and fix a time and place in March or April for the workshop. All other deliverables in the contract are complete and were described in the current proposal, with the exception of a set of measurements made in the Columbia R estuary. (Owing to the timing of the call for proposals for the estuary and ocean, we used a set of measurements for the Fraser River to illustrate the basic results in our proposal).

A set of measurements of the acoustic detection range in the mouth of the Columbia River estuary was completed after submitting the current proposal on Dec 12th (Fig. 1). The results, shown here, supplement and buttress the results we obtained in our field trials in the Fraser River estuary, and which we reported in the proposal. The measurements were made in an area north of the city of Hammond, on the far side of the shipping channel, and south and slightly to

the east of Sand Island (46° 14.801'N, 123° 56.854'W). The results we obtained for the Columbia River measurements are very similar to the measurements we obtained in the Fraser River, and allow us to define how to place the acoustic nodes on the bed of the Columbia estuary. In the Columbia River estuary study, we found that we obtained detection probabilities of >90% for individual transmissions using low-acoustic power output tags of the type we would use in our proposed study.

The remainder of the final contractor's report will largely be based on pieces of the existing proposal, plus the manuscript submitted to Transactions of the American Fisheries Society (The reviewers recommend publication subject to revision. They commented that the surgical study was notable because of its unusual duration (10 months) and because we demonstrated that it was possible to use much larger tags as a proportion of body weight than the previously accepted rule of thumb).

The purpose of this proposal is "to expand research on the acoustic tag and develop a prototype array which will allow demonstrating the capabilities of the technology to establish both river and ocean movements of chinook salmon (page 5)." The author states that the basic technology is now commercially available and the efficiency of its components has been tested. However, he does also note that "the logistics of deploying the equipment and gathering the data from fish tagged at various locations will require extensive effort over a wide geographic area. Deployment of equipment in the ocean will require significant R&D design effort (in particular, we intend to place the entire array sub-surface so that surface floats vulnerable to vessel traffic, fishing activities, and "curious" individuals are eliminated). Designs have been developed and partially field-tested for deploying the equipment on a semi-permanent basis to withstand the severe conditions that may be encountered at various sampling sites."
The statement is correct. As we comment below, we now have further empirical evidence that long-term deployments of this acoustic technology are possible. We stand by our original statement that this will require significant effort, but believe that the information that would be derived from this effort would be of significant public policy benefit to the Columbia River basin.

Concerning the results presented, the ISRP did note that studies of the biological response of smolts to the acoustic tag implantation were conducted on steelhead and that the proposal focuses on spring chinook. The author may also be interested that there are yearling fall chinook reared in the Snake and upper Columbia River that would also be large enough for tagging.
We chose to use steelhead rather than chinook smolts in the surgical trials for logistical reasons, and with the consent of the contracting officer, Alan Ruger. We would agree with what the ISRP appear to be suggesting, which is that tracking fall chinook down from their natal regions would be of considerable interest, and provide additional comparative material on in-river movements in the upper reaches of the watershed to that which we should obtain for the spring-summer yearling chinook. However, it was our original philosophy to minimize, as much as possible, any possible biological criticism that the animals we would track were somehow "tainted" by their rearing history. (This point, of course, also applies to the widely applied magnetic CWTs applied to the snouts of salmon smolts, since salmon are believed to migrate partly using magnetic fields,

and might also apply to animals either handled by humans or whose size was increased by selective rearing practices).

Nevertheless, we think that there is much advantage to tagging the animals in a way that most closely mimics the conditions experienced by the major life history types. We would welcome further suggestions as to which groups we would choose to tag, since the principle of the proposal would be strengthened by selecting the most representative animals.

"The importance of this technology is that it provides a means to actually measure migration rates (not necessarily migration paths, they will be inferred between two points), residency time in an area (e.g., within the Columbia River plume), and mortality rates".

We agree. We would point out a philosophical point, which is that any technology measures migration rates, not paths, since the tracking interval between successive positions is not infinitely small. However, although the distance between detection points we are proposing is relatively large, an advantage of the acoustic tracking array is that its components are scalable to the physical size of the issue (subject to the caveat that this technology will not work for fixing positions to physical scales less than ca. 1 km). For larger scales, the technology can simply be scaled by adding or moving detection lines to supplement those already present.

Although we would agree that our proposed technology may be well suited to measuring mortality rates at sea for Columbia River salmon smolts, we have not emphasised this potential role for the array as yet. It will simply not be possible to make pronouncements about the efficacy of the array for measuring mortality until we know what the probability of non-detection for individual animals will be under realistic field conditions. We are aware of the interest there is in the region in being able to measure mortality rates at sea (especially on a stock-specific basis), but believe that it will not be possible to answer potential critics of the methodology until the array is built on a significant spatial scale. At this point it will be possible to directly measure the frequency that a migrating smolt fails to be detected on one or more acoustic listening lines, but is then subsequently detected on more distant lines[1]. From this data, it is reasonably straightforward to make credible probabilistic statements about the reliability of mortality rates derived from the array. We will be making significant effort to analyze the data from the array in the first year or two of operation to obtain this information, which will then guide us in evaluating the capabilities of the array to make measurements of marine mortality rates for specific stocks of salmon smolts, in addition to the measurements of ocean distribution and migration we are proposing as the primary product from this research.

Since the ISRP review came out, we have had several discussions with NMFS as to the application of the acoustic array to answer questions concerning the degree to which Columbia

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[1] Our measurements of the rate of detection of false positives (i.e. serial numbers of acoustic tags recorded as present when they are not) is currently on the order of only 1 in 10^5 detections when multiple tags are simultaneously transmitting and therefore generating significant potential interference. These rates are sufficiently small that they are likely to be of insignificant influence in the calculation of rates of mortality at sea.

River salmon smolts remain resident within the Columbia River plume. If the NMFS estuary-plume study continues we believe it would be straight-forward to develop a small subsequent proposal to help NMFS assess residency time for the salmon that they are studying in the plume, and (eventually) to assessing which stocks their measurements apply to. As it has not been possible within the time frame of this review to incorporate an additional component to the project that would address the question of what fraction of the Columbia River salmon smolts entering the plume remain there, or to determine residence time for them, we propose that this be done by developing a separate, supplementary, project.

If the region agrees to the importance of establishing residence times within the Columbia River plume for salmonids, we would propose that this be addressed by developing a supplementary proposal jointly between NMFS and Kintama Research as sub-contractor. In brief outline, this proposal would use our existing array, since (see below) this would provide a series of 4 detection lines to the south of the Columbia River plume and multiple lines to the north to establish the movement and timing of tagged salmon out of the plume, and demonstrate whether departing salmon subsequently returned to the plume. We estimate that in addition to the existing proposal, roughly 40 additional receivers placed just beyond the average boundary of the plume (and perhaps 20 receivers placed under the plume) would provide fine-scale evidence for long-term residence within the plume environment itself. The number of salmon that would need to be tagged to identify residence within the plume is beyond the time available for this initial response to the ISRP's comments and would therefore need to be quantified later. We would suggest that the Year 1 (2003) results from the current proposal would provide the best estimate of the proportion of smolts non-resident in the plume, and the timing of their movements out of the plume.

Although it is clear that the plume is used by some proportion of West Coast salmonids, and may be a major habitat for some, long-term use by the majority of Columbia River smolts seems unlikely (given the large number of smolts exiting the Columbia river, and the evidence for very rapid northward migration of some fraction of the Columbia River salmon smolts). It seems to us most likely that some specific stocks may possibly have adapted to use the plume as their primary habitat. However, because the plume is such a small area compared to the area of the shelf known to contain Columbia River juveniles, it would seem advisable to first address the question of what proportion of the spring and fall-type smolts we propose to tag in our existing proposal remain within the vicinity of the plume in 2003, and then to focus a supplementary proposal in later years on identifying stock-specific residence times for those animals remaining very precisely in or near in the plume itself. The results from the existing proposal should provide a firm basis for designing these supplementary studies. Additional smolts could be tagged in and out of the plume environment to supplement the 200 smolts proposed for tagging along the Oregon-Washington coast in August-September. These tagged smolts would provide important information on how smolts move relative to the plume prior to the August tagging and some assessment of fidelity to the plume environment.

"… in our assessment, this proposal is too large a next step in the development of the technology and the "proof in principle". Before expenditures in the millions for receivers etc., there is a responsibility to develop the arrays, deployment processes, and methods for

data capture. There is little value in testing a hypothesis unless the uncertainties of the new technology can be addressed or eliminated. The ISRP continues to support this innovation and the efforts of this investigator but we recommend that a revised and reduced proposal be submitted. The development and testing of receiver arrays should be priorities in the short-term and then scaling up to a network of coastal arrays over time if demonstrated to be successful (i.e., re-profile costs over time and after demonstrated successes). …However, the principles could provide important information to the Columbia Basin if the revisions first address in-river movements and then residence time in and around the Columbia plume."

Because of the need to secure the equipment within the limited time frame remaining by the autumn of this year, and the ISRP's concern about the scale of the deployment, we propose to stagger the deployment as follows (Table 1). In the first field year (2003), we would propose to put in place the 12 in-river receivers, plus the 8 lines proposed for the Washington-Oregon coast. In addition, we would propose putting in a subset of the receivers for the west coast of Vancouver Island (3 cross-shelf lines extending to the 100m isobath, plus the relatively small number of receivers placed in West Coast inlets (24 receivers)). As our original proposal outlined, these inlets appear to be major chinook rearing areas and key overwintering locations.

In the second field year (2004) we would propose to put in place the remainder of the 31 receivers specified for British Columbia, plus put in place all the receivers identified for SE Alaska (Tables 1 & 2). We have assumed a 20% loss rate per year for receivers previously deployed. As our discussion below indicates, recent experience in the Atlantic suggests that the probable loss rate will be closer to 15%.

We view the cross-shelf lines on the west coast of Vancouver Island to be important to the initial phase-in period because a significant proportion of Columbia River chinook smolts appear to move rapidly up along the west coast of Vancouver Island. Snake River chinook smolts are detected off the north end of Vancouver Island by the first week of June, which requires sustained swimming speeds of ~2 BL/sec. Some of these tagged Snake River smolts are also apparently detected off SE Alaska only a few weeks later. If there are substantial detections of migrating Columbia River smolts off the northern end of Vancouver Island in year 1, this will provide further justification for deploying the SE Alaska portion of the array in year 2.

If major problems are identified in year 1 with reference to either the logistics of deployment and recovery, or if a significant number of tagged smolts are not identified migrating north past the west coast of Vancouver Island, then we would propose that a meeting be held to discuss the results after consultation with the BPA scientific authority. At this point it would be possible to reformulate the objectives if there is significant evidence that the array is failing to meet its potential.

A relatively extensive array is an important first phase, because it will provide the multiple detection lines necessary to establish the rate of non-detection of tagged smolts on the acoustic lines as they move north (or south). Our calculations suggest that the use of multiple detection lines is preferable to a strategy of a few detection lines heavily populated with receivers (passing

boats, rain, or storms can allow a smolt to pass by undetected under severe conditions; however, it is unlikely that these conditions will re-occur just as the smolt reaches subsequent detection lines). By measuring the proportion of lines that each smolt goes undetected on while still being subsequently detected farther away, a rough estimate of the non-detection rate can be obtained. With several hundred tagged smolts released and entering the ocean in 2003, the estimate of the probability of non-detection can be substantially refined, and we should then get quite a precise estimate of the rate of non-detection. Obtaining this value should provide a sharp focus to further assessment and debate prior to planned deployment of the other receivers in 2004.

We are confident that it is logistically possible to put in place these long-term detection lines. Work in the Bay of Fundy (Lacroix, personal communication) has involved the development of a summer-time tracking network of ca. 200 receivers which has been used to successfully track the movements of over 1,000 acoustically tagged Atlantic salmon smolts in 2001. The Bay of Fundy has the largest tides in the world, and very severe tidal currents. A second study by a different group of Atlantic scientists, currently under review, reports on the deployment of a 160 km long acoustic detection line, with receivers spaced every 2 kms on the seafloor. The line was deployed for 1 yr. Despite the use of a very simple system for deployment and recovery (individual Vemco receivers were grappled from the seafloor), a nearly 90% recovery rate was achieved. This single detection line detected a very high proportion of the tagged cod at the start of their winter migration, and subsequently redetected the animals on their return migration the following spring. The authors of the study commented that receivers provided unprecedented information on migration routes and migration timing, and the results were significantly clear-cut to modify the management of the fishery.
In addition, two continuous detection arrays will be deployed in April to June of this year off the West Coast of North America as part of the Census of Marine Life project "POST". The longer line will be ca. 20 kms long and consist of 28 acoustic receivers, and the shorter line will be approximately 5 kms long. These detection lines are intended to seal off Queen Charlotte Sound (the large body of salt water lying between Vancouver Island and the mainland and just north of Johnstone Strait) to and will provide both an extensive test of the ability to detect the movements of multiple tagged steelhead smolts and kelts over these lines, and further proof of principle that large scale detection lines can be deployed in the Pacific Ocean. While it is not possible to prove that the large-scale Pacific experiment will be successful, we suggest that the ISRP's concerns be recognized by recommending that final sign-off be made conditional on the funding body being satisfied that progress continues to demonstrate successful likelihood of being able to achieve the proposed results.

In summary, these results demonstrate that the acoustic tracking equipment is already being used in analogous situations to that proposed here, demonstrating that successful large-scale and long-term deployments are possible. The planned deployment off Vancouver Island in the summer of 2002 will provide further demonstration in a Pacific context and additional experience. In our view, the next logical step in 2003 is to establish the first phase of a large-scale (multi-line) West Coast tracking array. This step will allow us to establish large scale movement patterns of key Columbia River salmon stocks in the ocean and to fine tune the capabilities of the technology. Such information will not be forthcoming from a small scale deployment centred only in freshwater or very near the Columbia River plume. We recognise the

concern for making sure the deployment is logistically feasible, but would argue that failing to provide for the opportunity to measure the capability of the array to measure the "big picture" will also slow down the ability to scientifically assess its true utility.

Table 1. Summary of the proposed phase-in schedule for the acoustic array, by year.

Deployment Year	River	Washington - Oregon	British Columbia	SE Alaska	Total Receivers Deployed
2003	12	117	57		186
2004	2	23	42	105	172
2005	2	23	18	21	64
2006	2	23	18	21	64
2007	--	--	--	--	0

Notes:

a) Annual totals reflect a combination of new receivers placed during the two-year phase in period, and replacement of previously deployed receivers

b) Equipment is assumed lost and replaced at a rate of 20% per year, except in the last year.

Table 2. Summary of the proposed phase-in for the acoustic array, by year. Detection lines 9, 16, and 21-32 are proposed for deployment in year 2 (2004), assuming that the results from year 1 are deemed acceptable to the BPA scientific authority on the project.

Washington/Oregon	Acoustic Receivers	British Columbia	Acoustic Receivers	Southeast Alaska	Acoustic Receivers
Line 1, Cape Sebastian	12	Line 9, Pachena Point	12	Line 24, SE Alaska I	6
Line 2, Cape Blanco	12	Line 10, Amphitrite Point	12	Line 25, Clarence Strait	8
Line 3, A	12	Line 11, Clayoquot Sound	5	Line 26, Summer Strait	20
Line 4, Cape Mears	12	Line 12, Sydney Inlet I	4	Line 27, Chatham Strait S	6
Line 5, N Cape Elisabeth	12	Line 12a, Sydney Inlet II	2	Line 28, Baranoff Island	12
Line 6, Destruction Island	12	Line 13, Nootka Sound	6	Line 29, Chatham Strait N	15
Line 7, Cape Flattery	20	Line 14, Esperanza Inlet I	3	Line 30, Stephens Passag	11
Line 8, Juan de Fuca	25	Line 15 Esperanza Inlet II	2	Line 31, C	15
		Line 16, B	12	Line 32, D	12
		Line 17, Brooks Peninsula	7		
		Line 18, Quatsino Sound I	2		
		Line 19, Quatsino Sound II	2		
		Line 20, Cape Scott	12		
		Line 21, Johnstone Strait I	3		
		Line 22, Johnstone Strait II	2		
		Line 23, Johnstone Strait III	2		
Proposed Regional Totals:	***117***		***88***		***105***
				Grand Total:	***310***

(a) Acoustic lines proposed for 2004 phase-in are indicated by shaded blocks

Attention should be given to the basis for budget estimates, in particular who the investigators will be and their involvement, and the basis for certain cost estimates. In the current budget, it is hard to understand a basis for Section 7 (Monitoring and Evaluation) costs given that the majority of those costs would seem to be labor for analytical time.

A. Investigators

The three primary investigators responsible for this proposal are Drs Welch & Batten, and Mr John McKern. Full CVs are attached to this response for all three investigators. Dr Welch was the originator of the concept of a West Coast acoustic tracking array for salmon and has been involved in developing methods for tracking individual animals at sea since 1995, and has developed large co-ordinated ocean research programs since 1990. He was also funded under the Council's Innovative proposal category to evaluate the acoustic tracking technology that this proposal directly depends upon. Since 1990 he has been focussed on studying the ocean biology of Pacific salmon, and has proposed, co-ordinated, and run several different collaborative international research programs on Pacific salmon in the ocean with the three other major salmon producing nations of the Pacific Rim (Japan, Russia, and the US). All of these programs have involved the co-ordination of ships and sampling from these platforms. As well as having a demonstrated ability to conceive and co-ordinate extensive marine sampling programs involving ship's crews from several countries (and both charter and government crews), he has also won a number of significant scientific awards for his ocean research. Dr Welch will be overall co-ordinator of the array deployment, and will be directly responsible for all aspects necessary for the initial co-ordination and subsequent at-sea placement of the array elements, and will lead the field crews involved in the surgical implantation work to ensure that technical standards for surgical implantation are met (an often overlooked issue). He has a Ph.D. in oceanography with a specialization in mathematical and statistical analysis, and will direct and co-ordinate most of the technical analyses of the data jointly with Dr Batten.

In the event that the array proposal is funded, it is Dr Welch's intention to request a three year leave of absence from his primary employer, the Department of Fisheries and Oceans. His High Seas program is well-established and the existing scientific and technical staff are clearly capable of executing the program to continue to develop the baseline information needed to document the growth and expected survival conditions for juvenile salmon migrating through or resident in shelf areas of British Columbia and SE Alaska. Dr Welch will use the time to build the skeleton array, prove the validity of the concept by applying it to an important public policy issue for the Columbia Basin, and seek broader use and support for the array. An important aspect of the large-scale array is that (properly co-ordinated so that duplicate tag numbers are not released) a single seamless tracking array for all the major rivers and the entire West Coast continental shelf can be developed. This will allow multiple users from all regions of the West Coast of North America to take advantage of the benefits of such an array, and to spread the costs widely amongst the varied research communities of the West Coast, both freshwater and marine.

Dr Batten is the former Deputy Director of the Sir Alister Hardy Foundation for Ocean Sciences (SAHFOS), in Plymouth, UK, and was responsible for the co-ordination of a scientific and technical staff of approximately 17, with direct line authority over four. Her Ph.D. is in Marine

Science. SAHFOS was founded to run the world's longest and most extensive plankton monitoring program, using the Hardy Continuous Plankton Recorder (CPR). This involved co-ordinating the shipping, deployment, and return of CPRs from many shipping routes each year, ensuring that the samples were processed, and that the data obtained were archived and made available to the marine science community. Dr Batten was also formerly heavily involved in a number of major international programs in the Atlantic Ocean that used these data, and has maintained a significant publication record. She has been involved as a co-PI on all the surgical trials funded under the current Innovative Proposal, and most of the field trials of the acoustic tracking equipment and subsequent analysis of the data derived from these trials. Dr Batten will be in charge of overseeing the day-to-day co-ordination of operations needed to successfully order, position, and deploy the equipment needed, assist with aspects of the field work, and co-ordinate the analysis of the data needed to evaluate the technical performance of the array after its deployment, and the movements of the tagged fish over the array.

Mr McKern was formerly employed by the Corps of Engineers as Chief of the Fisheries Management Unit, Walla Walla District. He has an M.Sc. in Fisheries Science with a minor in statistics. He has over 30 years of experience within the Columbia River basin on freshwater issues concerning salmon. Mr McKern was originally involved in the work when Kintama Research sub-contracted to him to supply a boat for the freshwater measurements made as part of the Innovative Proposal research last summer, and used his knowledge of the river to identify potential field test sites. Mr McKern will be brought into the current research proposal as a result of his ability to deal with the numerous permitting processes which need to be obtained to allow tagging of the salmon under NEPA, to co-ordinate with the hatcheries that would provide the source stocks used for the tagging, and to facilitate co-ordinating with the diversion facilities at mainstem dams where PIT-tagged fall-type smolts could be collected and tagged (We find the ISRP's comment that yearling fall-type chinook large enough to be acoustically tagged may be available very useful. Mr McKern will follow up and evaluate this possibility. If it is biologically reasonable we would prefer to use this approach, since it would provide movement data over the up-river array elements to compare with that obtained for the spring chinook, and because we have some concerns over the amount of time that might need to be spent at mainstem dams trying to collect a representative sample of PIT-tagged upriver smolts from specific stock groupings).

A number of individuals with considerable technical experience either in surgical implantation of tags or in the at-sea deployment of oceanographic equipment have been identified. In the event that the proposal is funded discussions will begin to secure their services. Technically well trained statistical analysts to assist with the preparation and analysis of the collected data will also be hired to assist with this aspect of the project.

<u>A. Budgets</u>
In the original preparation of budgets, we developed cost estimates for labor, travel, vessel, and equipment by major activities. In transferring these costs to the Council's task-based budget sub-sections, we did not include the indirect cost of activities to order, co-ordinate, and pre-position equipment into the direct cost categories (and thus did not adequately reflect directly associated costs). We had instead aggregated them in with costs for monitoring and evaluation,

a category which the ISRP rightly notes appear to be more associated with analytical tasks. In the revised budget these costs have now been shifted to the various tasks and now appear in the totals presented there.

The remaining major changes to the budget are as follows:

I. *We have phased in estimated costs for deploying the array over two years, as the ISRP suggested. We considered a phase in over three years, but concluded that this was not warranted for three main reasons:*

(1) A slower phase-in means that significant money must be spent on running a geographically restricted array over several years and a substantial amount on tagging in each year if we are to have sample sizes adequate to answer the critics; as a result, cost savings are not as large as might be thought.

(2) *We believe that the need to evaluate the capabilities of the array that are specifically built into our task-based budget statement under "Monitoring and Evaluation" will allow us to demonstrate for the contracting authority whether the array in Year I is working as expected; if it is not, there will be a need to re-group and re-assess at that time.*

(3) The time lines for outsourcing the equipment needed in year 1 will already be very tight if we are to meet the 2003 field season. If this proposal is successful, funding will not be established until roughly the early autumn of 2002, which leaves approximately 6 months to sign contracts and arrange for the manufacture and delivery of equipment to be deployed in April. Until contracts are signed, it is not possible to clearly schedule the procurement phase, partly owing to the available timelines, but also because it was (and still is) uncertain as to how smoothly the manufacturer can schedule the arrival of equipment from several suppliers. We believe that limitations on procurement in Year 1 are likely to play as large a role in the deployment as will our scheduling plans. It is not possible to have serious discussions with the manufacturers as to limits on their own time lines until we can demonstrate that we are in a position to sign contracts with them.

II. *During the development of the original budget estimates, we neglected to factor in a contingency factor for loss or failure of the acoustic receivers (seawater ingress, electronic failure, etc). We have assumed an estimated rate of equipment loss of 20% per year in the revised budget calculations, with no provision for equipment replacement in year 5.*

III. *Final year costs for data retrieval are higher than for earlier years because in the final year of the project the boats are only used for getting data back - in previous years the boats are also used for replacing receivers (and in year 2 putting out other lines), so the costs of boat, salaries and travel in earlier years of the project have been split between the 3 categories.*

IV. *Out-year estimated costs for monitoring and evaluation are slightly higher than in year 1. This was the result of our assumption that if the results from year 1, focussed on demonstrating the validity of the array, were successful, then more effort would be devoted to broader range of*

analysis questions, and that additional staff time would be taken in presenting the results at meetings and preparing primary publications.

Attachment 1

Sonia D. Batten, PhD.

Curriculum Vitae

Personal Information

Date of Birth	1st May 1969
Citizenship	British citizen. Canadian Landed Immigrant
Email address	soba@mail.pml.ac.uk

Recent Employment History

2001-present **Kintama Research Corporation**

- Field work, data analysis, report writing

2000-present **Sir Alister Hardy Foundation for Ocean Science, UK**
Research fellow

- Co-ordinate and carry out research associated with the CPR survey of the North Pacific
- Publish and present results and seek further funding

1996–2000 **Sir Alister Hardy Foundation for Ocean Science, UK**
Assistant Director:

- Stand in for Director in his absence
- Responsible for day-to-day running of Continuous Plankton Recorder Survey
- Coordinate SAHFOS contribution to specific research projects
- Line management of 4 staff members
- Production of SAHFOS Annual Report

1994–1996 **Sir Alister Hardy Foundation for Ocean Science, UK**
Postdoctoral Research Fellow

- Conducting research using CPR data for the EU funded projects OMEX and NOWESP

Education

1990–1994 **Oceanography Dept., Southampton University, UK**

- PhD. *Correlative studies of the ecophysiology and community structure of benthic macrofauna.*

1987–1990 **Oceanography Dept., Southampton University, UK**

- BSc. Honours Degree in Oceanography with Biology, 2(i).

Research projects

Jan 2002 – Oct 2002 **Co PI** (with Dr D. Welch, Department of Fisheries and Oceans, Canada) on *A CPR-Based Plankton Survey Using Ships of Opportunity to monitor the Gulf of Alaska*

Exxon Valdez Oil Spill Trust Fund (US$112,000)

August 2000 – January 2002 **PI** on *Testing hypotheses on the causality of long-term changes in zooplankton abundance* UK NERC 'Marine Productivity' (£44,657)

April 2000 – June 2001 ***Co-PI*** *(with Dr G. Hays, University of Wales, Swansea, UK and Dr R. Harris, Plymouth Marine Laboratory, UK) on* Increasing the utility of data from the CPR survey *UK NERC 'Marine Productivity' (£45,761)*

July 1999 – November 2001 ***Co PI*** *(with Dr D. Welch, Department of Fisheries and Oceans, Canada) on* A Continuous Plankton Recorder Monitoring Program for the NE Pacific and Southern Bering Sea. *North Pacific Marine Research Initiative (US$250,000)*

June 1997-November 2000 ***PI*** *on* The Continuous Plankton Recorder Survey of the Iberian margin, OMEX II,II *European Union, Marine Science and Technology (ECU 112,000)*

December 1996-May 1997 ***PI*** *on* The impact of the Sea Empress oil spill on phytoplankton and zooplankton populations. *UK Environment Agency (£14,000)*

Seminars

November 1997. Departmental Seminar at University of Wales, Swansea, School of Biological Sciences. *'Why spend thousands of pounds monitoring plankton?'*

November 1999. Departmental seminar at Heriot Watt University (Dept. Biological Sciences), Edinburgh. 'The Continuous Plankton Recorder Survey, Past, Present and Future'

October 2000. Departmental seminar at University of Bristol, Dept. Biological Sciences. 'The Continuous Plankton Recorder survey – probably the best biological time series in the world……'

February 2002. Climate Impacts Group, University of Washington, Seattle The CPR – 'Now coming to an ocean near you!'

35+ other conference and workshop presentations between 1995 and 2002.

Miscellaneous

SAHFOS representative to the Living Marine Resources Global Ocean Observing System (LMR-GOOS) Panel. Attended panel meetings in Montpellier, France (March 1999), Talcahuano, Chile (Dec. 1999) and Hawaii (May

2000)

Participant in three research cruises.

Co-supervisor to Robin Clarke (PhD CASE Student) 1996-2000, Thesis title 'Long term changes in the North Sea Ecosystem'

Publications

Welch, D.W., Batten, S.D. and Ward, B. (in press). Growth, survival, and tag retention of surgically implanted acoustic tags in Steelhead Trout *(O. mykiss*). (Transactions of the American Fisheries Society)

Batten, S.D., Welch, D.W., and Jonas, T. (In press). Latitudinal differences in the duration of development of *Neocalanus plumchrus* copepodites. (Fisheries Oceanography)

Beare, D.J., Batten, S., Edwards, M. and Reid, D.G. (In press). Prevalence of Atlantic, Pseudoceanic and Neritic zooplankton in the North Sea between 1958 and 1998 in relation to temperature, salinity, stratification intensity and Atlantic inflow.

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Attachment 2

Natural Resources
INTERNATIONAL
LTD.

CURRICULUM VITAE

John L. McKern
1444 Lowell Drive
Walla Walla, WA 99362-9331
Phone: (509) 525 6283
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OBJECTIVE:

Consulting Contract for Development of Fish Passage Facilities and Fish Habitat Improvement

ACADEMIC PREPARATION

1968 - 1971: Oregon State University, Master of Science in Fisheries Science
Master's Thesis: Steelhead Trout Otoliths for Age, Race, and Stock Analysis; Minor: Statistics

1965 - 1968: Oregon State University, Bachelor of Science in Wildlife Science

1963 - 1965: University of Oregon, Major: Biology

PROFESSIONAL EXPERIENCE

2000 - present: Proprietor of Fish Passage Solutions, President of Natural Resources International, LTD.

- Technical advisor on fishery issues to the Office of the Governor, State of Idaho
- Technical advisor on fishery issues to Potlatch Corporation

- Subcontractor to HDR Engineering for modification of juvenile fish bypass facilities at Walla Walla District, US Army Corps of Engineers dams
- Environmental consultant for preparing Section 404 Clean Water Act permit applications
- Currently developing Natural Resources International to make expertise available to countries seeking sustainable environmental development

1988 - 2000: Chief of Fisheries Management Unit, Operations Division, Walla Walla District, US Army Corps of Engineers

- Managed fishery programs in Operations Division and at District dams
- Supervised biologist in charge of adult fish counting and adult passage programs at dams
- Supervised biologist in charge of juvenile fish passage programs at dams and Juvenile Fish Transportation Program
- Coordinated Operations Division response to National Marine Fisheries Service Biological Opinions
- Prepared environmental impact statement for Juvenile Fish Transportation Program in response to court order
- Represented Corps in law suits on Juvenile Fish Transportation Program and Biological Opinions
- Member of District steering committee for new fish facility development including development of surface bypass technology

1987 - 1988: Special Assistant to the Commander for Environmental Resource Policy, Walla Walla District, US Army Corps of Engineers

- Provided policy-level oversight to environmental programs in Planning and Operations Divisions including all environmental documentation for civil works and regulatory function programs
- Provided environmental education to all District elements
- Coordinated District response to Northwest Power Planning Council Fish and Wildlife Program

1981 - 1987: Chief, Environmental Resources Branch, Planning Division, Walla Walla District, US Army Corps of Engineers

- Supervised District environmental planning program including fisheries, wildlife, limnology, cultural resources, and environmental documentation
- Planned and budgeted environmental work for District
- Coordinated and administered fisheries research contracts with agencies and universities for District research program

- Originated and represented Corps on Fish Transportation Oversight Team and managed Juvenile Fish Transportation Program through 1982
- Coordinated District response to Northwest Power Planning Council Fish and Wildlife Program

1979 - 1981: Chief, Fish and Wildlife Section, Operations Division, Walla Walla District, US Army Corps of Engineers

- Responsible for fish passage and fish counting at five major multipurpose dams and fish management at eight reservoir projects
- Responsible for Operations Division input to Planning Branch for fish and wildlife compensation for lower Snake River dam and reservoir projects
- Coordinated wildlife mitigation development for Dworshak Dam and Reservoir project
- Responsible for wildlife studies on Snake and Columbia rivers for North Pacific Division, US Army Corps of Engineers
- Supervised fish and wildlife biologists involved in wildlife management and fish passage operations and studies
- Coordinated and administered fisheries research contracts with agencies and universities for District research program

1976 - 1979: Supervisory Fish and Wildlife Biologist, Operations Division, Walla Walla District, US Army Corps of Engineers

- Responsible for fish passage and fish counting at five major multipurpose dams and fish management at eight reservoir projects
- Responsible for Operations Division input to Planning Branch for fish and wildlife compensation for lower Snake River dam and reservoir projects
- Coordinated wildlife mitigation development for Dworshak Dam and Reservoir project
- Responsible for wildlife studies on Snake and Columbia rivers for North Pacific Division, US Army Corps of Engineers
- Supervised fish and wildlife biologists involved in wildlife management and fish passage operations and studies
- Coordinated and administered fisheries research contracts with agencies and universities for District research program
- Responsible for wildlife studies on Snake and Columbia rivers for North Pacific Division, US Army Corps of Engineers

1973 - 1976: Fish and Wildlife Biologist, Operations Division, Walla Walla District, US Army Corps of Engineers

- Responsible for fish passage and fish counting at five major multipurpose dams and fish management at eight reservoir projects
- Responsible for Operations Division input to Planning Branch for fish and wildlife compensation for lower Snake River dam and reservoir projects
- Originated Tri-Agency Team and coordinated wildlife mitigation for Dworshak Dam and Reservoir project
- Responsible for wildlife studies on Snake and Columbia rivers for North Pacific Division, US Army Corps of Engineers

1971 - 1973: Fishery Biologist, Operations Division, Walla Walla District, US Army Corps of Engineers

- Responsible for fish passage and fish counting at five major multipurpose dams and fish management at eight reservoir projects
- Responsible for developing aquatic weed control program for Tri-Cities levees and drainage system

1968 - 1971: Biological Aide and Laboratory Instructor, Department of Fisheries and Wildlife, Oregon State University

- Organized and taught Economic Ichthyology 274, 275, and 276 laboratory sections
- Assisted graduate students with research studies on effects of aquatic herbicides on salmonids, distribution of lampreys in Oregon, stocking rates for warmwater gamefish in Oregon, and stocking rates for pen-rearing of channel catfish

AREAS OF EXPERTISE

- Fish and wildlife mitigation measures for hydroelectric and flood control dam and reservoir projects
- Design concepts for fish passage structures and facilities
- Sizing and design of fish hatcheries for mitigating fish losses
- Computer modeling for estimating fish losses through hydropower dams and systems, and estimating benefits from mitigation measures
- Planning and development of wildlife mitigation projects for dam and reservoir projects
- Fish passage improvements and diversions for irrigation projects
- Analysis of fish and wildlife issues related to development and operation of hydropower systems
- Interagency coordination for development and operation of hydropower system dams

- Contract development and administration for fish research and for fish and wildlife operations related to dams
- Development and design of fish passage equipment including bypass systems at dams and fish transportation trucks and barges
- Conduct of environmental assessments and preparation of environmental documentation for development projects
- Endangered Species Act permitting and compliance measures
- Environmental training and compliance teaching

ACHIEVEMENTS IN RELEVANT DISCIPLINE

- Improved adult fish counting facilities at five major dams
- Improved fish counting techniques at eight major dams
- Improved fish management at eight dam and reservoir projects
- Improved procedures and increased research efforts for gathering fish and wildlife information for mitigation of impacts of hydroelectric developments
- Participated in interagency negotiation and management meetings
- Originated inter-agency team concepts for conducting wildlife mitigation development at Dworshak Dam and Reservoir and for the Fish Transportation Oversight Team
- Provided environmental leadership for feasibility studies for hydropower and flood control projects in the Snake River Basin
- Coordinated District gas abatement programs and District water quality programs
- Coordinated and prepared environmental assessments and impact statements
- Steering committee member for development of new fish bypass technology
- Represented US in international fisheries meetings and symposiums in Sweden and Japan
- Represented Northwest Division of Corps at National Symposium of Fish Passage

STANDARDS OF SCIENTIFIC INTEGRITY, INDEPENDENCE, AND OBJECTIVITY

- Active in improvement of scientific procedures and techniques in the Corps' fisheries research program for nearly 30 years
- Advocate of gathering and relying upon scientific information to make biological decisions
- Represented Corps in origination of the Corps' wildlife research program
- Stresses independent thinking in review of fish and wildlife problems, and recommends solutions supported by scientific evidence
- Independence and objectivity resulted in retention as a fisheries advisor to the Office of the Governor, State of Idaho, including technical support to the Idaho Northwest

Power Planning Council Representative, the Idaho Office of Species Conservation, and the Office of the Attorney General of Idaho
- Because of integrity and objectivity, served as speaker and tour guide on innumerable tours of District projects and fish facilities for dignitaries and interest groups ranging from Secretary of Interior, Secretary of the Department of Commerce, and the Chief of Engineers for the Corps, foreign dignitaries, and interest groups down to and including school groups
- International tours or speaking opportunities included groups from Russia, China, Norway, Argentina, Korea, Canada, and Japan

INTEREST AND ABILITY TO WORK IN INTERDISCIPLINARY SETTINGS

- Effectively represented the Corps of Engineer on numerous interagency committees for nearly 30 year, including the Fisheries-Engineering Research Technical Committee, the Wildlife Subcommittee, the Nitrogen Task Force, the Committee on Fishery Operations, the Anadromous Fish Evaluation Program, the Fisheries Research Needs and Priorities Subcommittee, the Scientific Review Subcommittee, the Fish Facility Design Review Subcommittee, the Tri-Agency Team, and the Fish Transportation Oversight Team
- Represented the Corps in interagency studies for environmental analysis and documentation of hydroelectric and flood control developments
- Represented the District in interdisciplinary programs to develop environmentally sensitive master plans dam and reservoir projects
- Represented the Walla Walla District on the Water Quality Team
- Represented Corps on interagency steering committee for US Fish and Wildlife Service reconnaissance level study for reintroducing salmon in the Snake River above the Hells Canyon Dam complex
- Represented Corps at Salmon Summit Conference and participated on Habitat Subcommittee
- Worked with state fish and wildlife agencies to develop more effective fish and wildlife management at Corps lands and reservoirs
- Worked with state and federal fish and wildlife agencies to develop more environmentally sensitive methods of restoring flood damaged streams in Oregon, Washington, and Idaho
- Worked effectively for nearly 30 years with engineers and supporting disciplines to mitigate fish and wildlife impacts from development and operation of hydroelectric and flood control dams and structures

KNOWLEDGE OF WEST COAST SALMON BIOLOGY, STATUS, OR HABITAT

- Knowledge of west coast fisheries attained by three years of teaching fish identification and fisheries management techniques to fish and wildlife students at Oregon State University, and assisting other graduate students with fishery research around the State of Oregon

- Knowledge of west cost anadromous fisheries attained by three years of research on steelhead trout and nearly 30 years of identifying and correcting fish passage problems for anadromous fish at Columbia and Snake River dams
- Knowledge of resident fish and anadromous fish habitat requirements attained by years of study of fish populations affected by the hydropower system, and from coordinated efforts with state, tribal, and federal fishery agencies to develop and carry out fish mitigation programs, develop project master plans, and to develop environmental assessments and impact statements
- Knowledge of population status and dynamics developed through years of work analyzing fish runs and the effects of hydropower development on such runs through the use of various computer models
- Training included attending courses available on fish passage development and fish habitat assessment, and teaching fish passage and fish management at workshops and symposiums

SCIENTIFIC ACCOMPLISHMENTS

- Organization of instructional notes into the Laboratory Notebook for Economic Ichthyology
- Development of a tool for removing salmonid otoliths for scientific study
- Original research findings that otoliths are the first ossified structures in developing steelhead embryos, and that otoliths are resorbed and spawning checks develop as they do in steelhead scales
- Modification of flash-board counting stations to submerged window counting stations at McNary, Ice Harbor, and Lower Monumental dams to improve fish counting accuracy
- Research leading to the fine tuning of adult fish facility operations
- Design concepts for better adult fish passage facilities, and improved facilities for trapping adult fish for research and for transport to upstream spawning facilities
- Criteria and design concepts for development of fish hatcheries, adult fish trapping and holding facilities, and fish acclimation ponds and release facilities
- Development of trucks and barges for fish transportation
- Innovative improvements to juvenile fish passage facilities at dams including oversight of research resulting in the development of submerged fish screen bypass systems, improved methods of sorting juvenile fish for transport, development of PIT tag detection and deflector systems, improvement of hydraulic and biologic conditions in juvenile fish bypass systems
- Improved environmental sensitivity in flood control activities including development of a policy that Corps' snagging and clearing operation would include oversight by a Corps Fishery Biologist
- Origination of interagency teams for implementation of wildlife mitigation and oversight of the Juvenile Fish Transportation Program
- Development of computer programs for analyzing the benefits of fish mitigation measures

- Origination of a wildlife subcommittee and expansion of Corps' programs to include wildlife mitigation and habitat stewardship in the Corps' master planning process

ABILITY TO FORGE CREATIVE SOLUTIONS TO COMPLEX PROBLEMS

- Few fishery problems are more complex that those of the Columbia and Snake Rivers. Over a 30-year career, creative solutions originated working with others have increased juvenile fish survival through the hydropower system from 1 - 20% in the 1970s to 35 - 65% in 2000. Juvenile fish survival has risen from 85% in the 1970s to over 96% at dams with full bypass systems. Juvenile fish bypass systems now provide 98% to 99.7% survival for juvenile fish. With fish transportation providing over 98% survival, over 90% of the Snake River yearling salmon and steelhead can be delivered below Bonneville Dam alive. Adult fish passage survival has increased to 97% per project, and in years when gillnetting mortality and gas supersaturation are limited, upstream survival can exceed comparable survival measured in the un-dammed Fraser River in British Columbia.
- Innovative solutions to fish passage problems have resulted in continued modification and improvement to fish screens, mining of bypass systems the full length of dam powerhouses, development of safe and effective dewatering systems to increase bypass efficiency and provide additional water for adult fish passage systems, development of new and better fish transport trucks and barges, and improvement of spillway structures to minimize gas supersaturation levels.
- Next to the Northwest Power Planning Council/Bonneville Power Administration Fish and Wildlife Program, the Lower Snake River Fish and Wildlife Compensation Plan was the largest compensation program undertaken to mitigate the effects of hydropower development on fish and wildlife resources.
- The Juvenile Fish Transportation Program is the largest program of its kind in the world.
- New innovative solutions include the development of the surface bypass systems to significantly reduce the level of spill required to give safe in river passage to juvenile salmon, the development of the behavioral guidance structure to divert fish away from powerhouse intakes before they are subjected to pressure changes in turbine intakes, and development of the raised spillway crest to eliminate the significant pressure changes fish are subjected to in normal spillway operations.
- Development of computer models that show the effects of various facility and program modifications, including analyses that show that current spill programs result in reduced, not increased, juvenile fish survival compared with maximum transportation of fish.

MEMBERSHIP IN PROFESSIONAL SOCIETIES AND CONSERVATION ORGANIZATIONS

- American Fisheries Society
- Rocky Mountain Elk Foundation

- Ducks Unlimited
- Walla Walla Watershed Alliance

PUBLICATIONS

Juntunen, E.T., C.E. Bond, and J.L. McKern. 1970. Laboratory Notebook for Economic Ichthyology, Fsh. 274, 275, 276. Bookstore Publication, Oregon State University, Corvallis, OR.

McKern, J.L. and H.F. Horton. 1970. A punch to facilitate the removal of salmonid otoliths. Calif. Fish Game, 56: 65-68.

McKern, J.L., H.F. Horton, and K V. Koski. 1974. Development of Steelhead Trout (*Salmo gairdneri*) Otoliths and Their Use for Age Analysis and for Separating Summer from Winter Races and Wild from Hatchery Stocks. J. Fish. Res. Board Can., Vol. 31(8).

McKern, J.L. 1975. Mitigation Can't Wait. In: Water Spectrum. US Army, Corps of Engineers. Washington, D.C.

McKern, J.L. 1976. Inventory of Riparian Habitats and Associated Wildlife Along the Columbia and Snake Rivers. Executive Summary: Vol. 1 of 7. Walla Walla District, US Army, Corps of Engineers, Walla Walla, WA.

Koski, C.H., S.W. Pettit, and J.L. McKern. 1989. Fish Transportation Oversight Team Annual Report –FY 1988, Transport Operations on the Snake and Columbia Rivers. NOAA Technical Memorandum NMFS F/NWR – 25, NMFS, Portland, OR.

Koski, C.H., S.W. Pettit, and J.L. McKern. 1990. Fish Transportation Oversight Team Annual Report –FY 1989, Transport Operations on the Snake and Columbia Rivers. NOAA Technical Memorandum NMFS F/NWR – 27, NMFS, Portland, OR.

Koski, C.H., S.W. Pettit, and J.L. McKern. 1991. Fish Transportation Oversight Team Annual Report –FY 1990, Transport Operations on the Snake and Columbia Rivers. NOAA Technical Memorandum NMFS F/NWR – 29, NMFS, Portland, OR.

Ceballos, J.R., S.W. Pettit, and J.L. McKern. 1992. Fish Transportation Oversight Team Annual Report –FY 1991, Transport Operations on the Snake and Columbia Rivers. NOAA Technical Memorandum NMFS F/NWR – 31, NMFS, Portland, OR.

Ceballos, J.R., S.W. Pettit, J.L. McKern, R.R. Boyce, and D.F. Hurson. 1993. Fish Transportation Oversight Team Annual Report –FY 1992, Transport Operations on the Snake and Columbia Rivers. NOAA Technical Memorandum NMFS F/NWR – 32, NMFS, Portland, OR.

McKern, J.L. 1995. Juvenile Fish Transportation Program Environmental Impact Statement. Walla Walla District, US Army Corps of Engineers, Walla Walla, WA.

McKern, John. 2000. Juvenile Salmon Migration on the Lower Snake River. In: Proceedings of an International Symposium on Dams, Reservoirs and Nature Conservation, Wetlands International Japan, Tokyo Japan.

McKern, John. 2000. Adult Fish Passage Facilities at Dams. In: Proceedings of a Nationwide Symposium on Fish Passage at Dams, Water Ways Experiment Station, US Army Corps of Engineers, Vicksburg, MS.

Attachment 3

DAVID WARREN WELCH, B.Sc., Ph.D. CURRICULUM VITAE

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Nanaimo, British Columbia
Canada V9R 5K6
Telephone: *(250) 714-3526* · ***Facsimile:*** *(250) 756-7747* ·
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Canada V9S 5P4 Tel: (250) 756-7747

Background

DATE OF BIRTH:	November 10, 1955.
CITIZENSHIP:	Canadian.
LANGUAGES:	Fluent in English & Japanese.

Professional Affiliations

AMERICAN FISHERIES SOCIETY
AMERICAN GEOPHYSICAL UNION
AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

Education

UNIVERSITY OF TORONTO *B.Sc., Biology & Economics, 1977*
DALHOUSIE UNIVERSITY *Ph.D., Oceanography, 1985. "A Study of the Effects of Density-Dependence and Age-structure on the Dynamics of Marine Fish Populations".*

Areas of Expertise

Biological and Fisheries Oceanography; Mathematical Population Dynamics; Operations Research; Statistical Analysis; Economics and Management of Natural Resources.

A. PROFESSIONAL EXPERIENCE:

2000– ***PRESIDENT, KINTAMA RESEARCH CORPORATION***
Kintama was incorporated in order to develop a vehicle for initiating new approaches for dealing with the problems of marine survival for Pacific salmon. It had become clear that traditional approaches to addressing these problems were not, by themselves, adequate for studying an animal whose dynamics in the marine environment were likely even more complicated than the biological diversity evident in freshwater. In the absence of a clearly articulated scientific strategy within established organisations for focussing on these issues because of the size of the ocean and its multi-national nature, it is intended for Kintama to serve as a bridge and a service organisation for the diverse constituencies who need the information a continental-scale acoustic array will provide.

1990- ***PROGRAM HEAD & RESEARCH SCIENTIST***
High Seas Salmon Program
Ocean Sciences and Productivity Division
Department of Fisheries & Oceans
Pacific Biological Station, Nanaimo, B.C.

1986-90 ***RESEARCH SCIENTIST, FRASER RIVER SOCKEYE PROGRAM***
Salmon Production Section, Dept. of Fisheries & Oceans
Pacific Biological Station, Nanaimo, B.C.

1984-86 ***POSTDOCTORAL FELLOW***
Groundfish Section, Dept. of Fisheries and Oceans,
Pacific Biological Station, Nanaimo, B.C.

1980-82 ***RESEARCH ASSOCIATE***,
Institute for Ocean Research
University of Tokyo, Japan

1980 ***JAPANESE PROGRAM (4 MONTHS)***
Osaka University of Foreign Languages
Osaka, Japan.

1977-80 ***PH.D. (OCEANOGRAPHY & FISHERIES MANAGEMENT)***
& 1982-84 Dalhousie University
Halifax, Nova Scotia
Canada B3H 4J2

B. AWARDS & RECOGNITION

2002 ♦ **External Examiner.** Memorial University of Newfoundland. Ph.D. Thesis defense of Mr David Robichaud *"Homing, Population Structure*

and Management of Atlantic cod (Gadus morhua), with emphasis on spawning at Bar Haven in Placentia Bay, Newfoundland". 4 February 2002.

- **Co-Chair.** Alfred P. Sloan Foundation's Pacific Census of Marine Life Project, "**POST**". (Joint with G. Boehlert). March 27, 2001.

2001 ♦ **Adjunct Professor.** School of Earth & Ocean Sciences, University of Victoria. Four Year appointment, July 1, 2001 – June 30, 2005.

- **Co-Chair.** Alfred P. Sloan Foundation's Pacific Census of Marine Life Project, "**POST**". (Joint with G. Boehlert). March 27, 2001.

2000 ♦ **Invited Plenary Address** at the Exxon Valdez Oil Spill Trustee Council, Restoration Workshop, on the effects of climate change and global warming on the ocean ecosystem "Applying Science to Human Needs: Starting the Transition to the Gulf Ecosystem Monitoring (GEM) Program". 18 January, 2000. Anchorage, Alaska.

- **Invited** presentation on my ocean research program and a review of expected impacts of global warming on Pacific salmon to the senior executive committee (CEO and all senior Vice-Presidents and aides) of the Bonneville Power Administration: *"Effect of Ocean Climatic Shifts on Growth and Survival of Endangered Salmon Stocks".* Bonneville Power Administration, Portland, Oregon. 3 February 2000.

- **Invited** presentation, Idaho State Legislature, House Resources & Conservation Committee. On my ocean research program and a review of expected impacts of global warming on Pacific salmon. Boise Idaho, 13 March 2000.

- **Best Paper Award**, *"Ocean Climate Effects on Pacific Salmon".* American Fisheries Society Annual Meeting, Idaho Chapter. March 2000.

- **Requested** to write the article on "Pacific salmon" for the *"Encyclopaedia of Global Environmental Change",* by John Wiley & Sons, Chichester.

- **Requested** to develop the Pacific concept paper for the Sloan Foundation's "*Census of Marine Life*". March, 2000

- **Nominated,** by the American Fisheries Society, for the Pew Award for Marine Conservation. May, 2000. (http://www.pewmarine.org/ProgramProfile/index.html)

- **Primary Reviewer**, NOAA-NSF Review Panel, U.S. West Coast GLOBEC Program, Silver Springs, Maryland, 24-26 July.

- **Organized** Sloan Foundation's Census of Marine Life Workshop *"Use of Electronic Tags for Tracking Pacific Salmon"*. 8-9 December, Vancouver, British Columbia.

1999 ♦ **Invited** (as one of two scientific experts) to lead a "Press Backgrounder" for the World Wildlife Fund on Oceans Day (June 8, 1999). The purpose of the Backgrounder was to provide science & environment journalists from leading news agencies with the background information on my research into the probable impacts of global warming and climate change on Pacific salmon populations. 8 June 1999, National Press Club, Washington D.C.

- **R.E. Foerster Award.** *Outstanding Scientific Publication for 1998.* (D.W. Welch, Y. Ishida, and K. Nagasawa. (1998) Thermal Limits and Ocean Migrations of Sockeye Salmon (*Oncorhynchus nerka*): Long-Term Consequences of Global Warming. Can. J. Fish. Aquat. Sci. 55:937-948). http://www-comm.pac.dfo-mpo.gc.ca/english/release/p-releas/1999/nr99117e.htm

- **R.E. Foerster Award (Honourable Mention).** *Outstanding Scientific Publication for 1998.* (D.W. Welch, Y. Ishida, K. Nagasawa, and J.P. Eveson. *1998.* Thermal Limits On The Ocean Distribution Of Steelhead Trout (*Oncorhynchus mykiss*). *In:* D.W. Welch, D.M. Eggers, K. Wakabayashi, and V.I. Karpenko (*Editors*), *"Assessment and Status of Pacific Rim Salmonid Stocks"*. N. Pac. Anadr. Fish Comm. Bull. No. 1:396-404.)

- **Requested to testify** as an expert witness on the results of my research into changes in ocean conditions on Pacific salmon populations and their migratory pathways at the United States Senate Energy and Natural Resources Oversight Committee, in Washington, D.C. 9 June 1999. Senator Gordon Smith, Chair.

- **Research findings presented** to the Federal Cabinet as one of the best examples of the potential effects of global warming on Canadian resources.

- **Invited to teach** the annual *"Two Day Short Course" on* ***"Ocean Processes and Salmon Ecology".*** *The course was taught to ca. 200 professional biologists and fisheries managers of the Alaska Dept. of Fish & Game.* The invitation was of particular significance because of the continuing impasse since 1993 between Canada and Alaska over the Pacific Salmon Treaty. The request marked a significant change in Alaska's stated position that salmon management problems in Canada and the Pacific Northwest were caused by poor management and freshwater habitat degradation. For the first time Alaska acknowledged the importance of ocean processes in affecting its management of Alaskan salmon resources, and invited a Canadian scientist to train its professionals on the issue. The course was taught jointly with Prof. Tom Royer, (Eminent Professor & Samuel L. and Fay M. Slover Chair of Physical Oceanography, Old Dominion University) at the Alaskan Regal Hotel in, Anchorage Alaska, on 8-9 March 1999.

- **Program Advisor** to Trout Unlimited's Alaska Salmonid Biodiversity Program. (20 Dec 1999)

1998 A report in the journal *Science* (Research News section, vol. 280, p. 1349, 1998) referred to our published (1998) work on the thermal limits of sockeye salmon and the potential effects of climate change as "*… a major study of enormous importance highlighting the need to study salmon throughout their natural environments*". Following the *Science* review the Canadian Broadcasting Corporation (CBC) led the May 27th national news with a 2 ½ minute report on the global warming study and DFO's High Seas Salmon research program. Many radio and TV interviews followed, including a 7 minute TV piece on Discovery Channel "Science News" and the U.S. National Public Radio, plus other vignettes in "Arctic Science Journeys", The Rafe Mair show (CKNW Radio, Vancouver), CBC Radio and TV shows, "Earthwatch Radio" (National Public Radio, Wisconsin), plus other British Columbia TV news shows. Public comments on the potential dangers of global warming based on these research findings were also made by both President Clinton and Vice-President Gore (the latter, correctly). The research was also picked up and reported on by many U.S. newspapers. An excellent

extended 1/2 page review of this work for the general public also was run by the Globe and Mail on page 2 of the Tuesday, June 2nd 1998 issue:
(*URL:* http://www.theglobeandmail.com/docs/archive/19980602/Compass/ucompn.html).

- ***"Wonders of the Earth—The Adams Salmon Big Run".*** An NHK (Japan) 1 hour television documentary on the Adams River Salmon Run, with an extended interview on how our ocean research program is providing new insight into the biology of this run, and the potential future impacts of global warming. (First aired in Japan on 22 November 1998)

1997 ***"Phantom of the Ocean".*** A 1 Hour CBC (Canadian Broadcasting Corporation) Television Documentary focussing on my research in DFO on climate change and ocean biology of salmon. The show was subsequently re-aired several times.

1997 ***R.E. Foerster Award.*** Outstanding Scientific Publication for 1995. *(D.W. Welch, A.I. Chigirinsky, & Y. Ishida (1995) Can. J. Fish. Aquat. Sci. 52:489-503)*

1992 ***1992 R.E. Foerster Award*** (Honourable Mention).

1984-86 Natural Sciences and Engineering Research Council of Canada Visiting Scientist in Canadian Government Laboratories Fellowship

1982-84 Dalhousie University Graduate Fellowship.

1980-82 Monbusho Research Fellowship.

1977-80 Dalhousie University Graduate Fellowship.

EXTERNAL RESEARCH GRANTS AND OTHER SCIENTIFIC SUPPORT (Since 1990).

2002	***Exxon Valdez Oil Spill Trustee Council.*** One year continuation award to fund a *"CPR-Based Plankton Survey using Ships of Opportunity to Monitor the Gulf of Alaska".* Joint with S. Batten. $191,500
2001-2003	***Alfred P. Sloan Foundation, Census of Marine Life.*** Award to begin the Planning Phase for **"POST"**, the Pacific Ocean Salmon Tracking Project. $618,000

2001-2003	**Australian Research Council.** Big squids in Australian waters, insights into their biology, movement and activity, old questions - new technology (*Accepted*) G. Jackson (University of Tasmania, Lead PI) & D. Welch (Overseas Chief Investigator). $280,000 (Aus)
2000	***Alfred P. Sloan Foundation, Census of Marine Life.*** Award to fund a workshop to develop a Pacific Ocean Pilot Program using electronic tags on Pacific salmon. $45,000
2000-2001	**Bonneville Power Administration.** Collaborative Agreement. $625,000. *"Canada-USA Shelf Salmon Survival Study".*
2000-2001	***Canadian Climate Change Action Fund.*** Climate Change Impacts on Pacific Salmon. $6,000
1999-2000	**Bonneville Power Administration.** Collaborative Agreement. $420,000. *"Canada-USA Shelf Salmon Survival Study".* Initial six month award.
1999-2001	**World Wildlife Fund.** Two year award. *$60,000.* To support a Post-Doctoral Fellowship on a bioenergetic analysis of the mechanisms determining thermal limits of Pacific salmon.
1999-2001	**North Pacific Marine Research Initiative.** Two year award. *$375,000. "A Plankton Monitoring Program for the North Pacific Ocean".* (Joint with S.D. Batten, Deputy Director, Sir Alister Hardy Foundation for Ocean Studies, Plymouth, UK)
1999-2003	**Nestucca Oil Spill Trustees Grant.** Five year award. *$150,000.* "*Monitoring of marine biota and oceanographic conditions in the Triangle Island Region*".
1996-2000	**GLOBEC-Canada Grant**. Four year award, $40,000 *p.a. "Zooplankton and Oceanographic Effects on Ocean Salmon Growth***".** (Joint with R.I. Perry)
1996-97	**Canada-U.S. Salmon Research Program**. $25,000 *"Marine Survival of Fraser River Sockeye and Pink Salmon*". (Joint with R.J. Beamish)
1994-1997	**Dept. of External Affairs**. Japan-Canada Science and Technology Grant. $350,000 over three years (1994/95: $105,000; 1995/96: $120,000; 1996/97: $125,000; Maximum award permitted under funding regulations). ***"****Effects of Climate Change and Salmon Abundance on the Sustainable Yield of North Pacific Salmon****".***
1991-1993	**Dept. of External Affairs**. Japan-Canada Science and Technology Grant. Three year award (1991/92: $25,000; 1992/93: $30,000; 1993/94: $30,000). ***"****Long-term Environmental Controls on the Sustainable Development of*

	*North Pacific Salmon***".**

C. ***RESEARCH AND TEACHING EXPERIENCE***

8-9 March, 1999 "Two Day Short Course" on ***"Ocean Processes and Salmon Ecology"*** *for the Alaska Department of Fish and Game.* (Joint with Tom Royer).

1993-2000. Principal and teacher, Japanese language instruction (Intermediate, Advanced, and Immersion).

23/09/86 - present. Research Scientist, Department of Fisheries & Oceans, Nanaimo B.C.
Primary areas of research: Research on the distribution, migration pathways, and high seas ecology of Pacific salmon. The purpose of this work is to define the carrying capacity of the North Pacific Ocean for salmon, and the effect of climate change and carrying capacity on sustainable yield of salmon fisheries. In addition, I have conducted research on age-structured population dynamics, development of new methods for measuring and establishing vital rate processes, and the development and application of new statistical estimation, operations research, and time series analysis techniques in the search for new techniques applicable to the rational management of Pacific salmon.

27 November 1984 - 22 September 1986. Government of Canada Postdoctoral Fellow, Department of Fisheries & Oceans, Pacific Biological Station, Nanaimo B.C. ***Primary areas of research:*** Research on age-structured population modelling, and development of new methods for measuring and establishing vital rate processes.

1983 - 1984. Teaching Assistant, Fisheries Population Dynamics. Department of Oceanography, Dalhousie University.

April 1980 - March 1982. Monbusho Research Fellow, Ocean Research Institute, University of Tokyo, Japan. Research on age-structured population modelling.

1979. Teaching Assistant, Advanced Biometrics. Department of Biology, Dalhousie University.

May - Sept. 1976 & May - Sept 1977. Ministry of Natural Resources, Fisheries Section. Maple, Ontario. Freshwater fisheries research.

May - Sept 1974 & May - Sept 1975. Ministry of Environment, Limnology Section. Etobicoke, Ontario.

C(2). STUDENTS

Sean P. Cox. 1994-96. M.Sc. Thesis, Univ. of British Columbia, Dept. of Zoology *(Supervisory Committee).*

David Robichaud. 2002. Ph.D. Thesis. *"Homing, Population Structure and Management of Atlantic cod (Gadus morhua), with emphasis on spawning at Bar Haven in Placentia Bay, Newfoundland".* Biology Dept., Memorial University (External Examiner)

D. SEMINARS

1. "*On Stock & Recruitment, and the Problem of How and When*". Fisheries Research Branch, Dept. of Fisheries & Oceans. St. John's Nfld. 27 Sept. 1985.

2. "*A New Method for Examining the Stock-Recruitment Relationship and Density-Dependent Regulation during the Early Life History of Marine Fish*". Pacific Biological Station, Nanaimo, B.C. 16 Oct. 1985.

3. "*Identifying the Stock-Recruitment Relationship in Age-Structured Populations*". Marine Sciences Research Center. State University of New York, Stony Brook, NY. 21 Nov. 1985.

4. "*A Maximum Likelihood Methodology for Estimating Length-at-Maturity with Application to Pacific Cod (Gadus macrocephalus) Population Dynamics*". 6th Annual Pacific Coast Resource Modelling Conference, Vancouver B.C. 11 June 1987.

5. "*Genzai no Canada Gawa Sake-masu Kenkyu ni Tsuite*". (The Current Status of Salmon Research in Canada; in Japanese). Far Seas Fisheries Research Laboratory, Shimizu, Japan. 19 July 1988.

6. "*Wiener-Optimal Estimation and the Stock I.D. & Age Misclassification Problems*". 1st Interdisciplinary Conference on Natural Resource Modelling and Analysis. Halifax, N.S. 1 Oct. 1988.

7. "*Canadian High-Seas Driftnet and Gillnet Research in the North Pacific*". 11 June 1991. Scientific Review Meeting on North Pacific High Seas Driftnet Fisheries, Sidney, British Columbia.

8. "*Upper Thermal Limits on the High Seas Distribution of Pacific Salmon*". University of British Columbia, Dept. of Oceanography. 25 August, 1991.

9. "*Age and Growth of Flying Squid (Ommastrephes bartrami)*". 4 November 1991. International North Pacific Fisheries Commission Special Symposium on "Biology, Distribution, and Stock Assessment of Species Caught in the High Seas Driftnet Fisheries in the North Pacific Ocean", Tokyo, Japan.

10. "*Optimal Management Strategies for Rebuilding the Fraser Sockeye.*" (**Invited Lecture**). University of British Columbia, Inst. of Applied Mathematics, 15 Jan. 1992.

11. "*Fraser Gawa no Beni Zake Shigen no Saidai Kanri Zoka Hoho ni Kan Shite*" (Optimal management strategies for rebuilding the Fraser River sockeye salmon resource; Invited). National Research Inst. of Far Seas Fisheries, Shimizu, Japan. 25 Jan. 1992.

12. *"*$\delta^{13}C$ - $\delta^{15}N$ *Anomalies as Indicators of Trophic Position and Competitive Overlap for Pacific Salmon (Oncorhynchus spp.)".* Calif. Co-op. Oceanic Fisheries Investigations. Annual Conference, 5 November, 1992. Monterey, Calif.

13. *"Upper Thermal Limits on the Late Spring Distribution of Pacific Salmon (Oncorhynchus spp.) in the Northeast Pacific Ocean".* Calif. Co-op. Oceanic Fisheries Investigations. Annual Conference, 5 November, 1992. Monterey, Calif.

14. "*Upper Thermal Limits on the Oceanic Distribution of Pacific Salmon and its Potential Influence on Oceanic Carrying Capacity*" **Guest Lecture**; 1992 Annual Meeting of the American Fisheries Society, Alaska Chapter; Valdez, Alaska, 17 November 1992.

15. *"Operations Research and Optimal Rebuilding of Fraser River Sockeye Salmon".* (**Invited Lecture**). Dept. of Applied Mathematics, University of British Columbia. Vancouver, B.C., 27 January, 1993

16. *"Maximum Likelihood Estimation in Fisheries Research: Tactics & Strategy in Professional Practice".* Oregon Dept. of Fish & Wildlife, Clackamas, Oregon. 5 March, 1993.

17. *"Upper Thermal Limits on the Oceanic Distribution of Pacific Salmon".* Dept. of Oceanography, University of British Columbia. Vancouver, B.C., 30 March, 1993.

18. *"Operation Research Techniques Applied to the Rational Management of Pacific Salmon".* Faculty of Commerce and Management Sciences, Univ. of British Columbia. Vancouver, B.C. June 11, 1993.

19. "*Oceanographic Controls on the Distribution of Pacific Salmon in the Subarctic North Pacific, and the Potential Impact of* $2xCO_2$ *Climate Change Scenarios*". Nemuro Workshop on Western Subarctic Circulation '93, Nemuro Japan, 20 September 1993.

20. "*Fushigi na Sakana: Sake no Umi no Seikatsu". (The Strange Fish: The Sea Life of Salmon).* Children's memorial lecture, given in Japanese at the

Nemuro Workshop on Western Subarctic Circulation '93, Nemuro Japan, 22 September 1993 to all Grade 5 students and teachers in the Nemuro School District (386 children, 20 teachers).

21. "*Oceanographic Controls on the Distribution of Pacific Salmon in the Subarctic North Pacific, and the Potential Impact of 2xCO_2 Climate Change Scenarios*". PICES 2nd Annual Meeting, Seattle, Wash., Oct. 27, 1993

22. *"Inter-annual Trophic Phasing in the Central North Pacific Ocean: Evolutionary Evidence for High Seas Competition in Pacific Salmon"*. PICES 2nd Annual Meeting, Seattle, Wash., Oct. 27, 1993

23. *"Thermal Limits and Oceanic Salmon Production under a Changing Climate"*. Pacific Biological Station, Nanaimo, B.C. Dec. 8, 1993.

24. *"Operations Research Techniques Applied to the Management of Canada's West Coast Salmon Fisheries"*. (**Invited Lecture**) Canadian Operations Research Society, Vancouver, B.C. Jan. 11, 1994.

25. *"Trends in Abundance of Salmon Species."* Marine Environmental Quality Monitoring Network, Pacific Ecozone Workshop. Victoria, B.C. 2 February, 1994.

26. *"Ocean Thermal Limits and Possible Impacts of Climate Change on Salmonid Growth in the Northeast Pacific Ocean."* **(Invited Lecture)** Workshop on Biophysical Controls of Salmon Migration and Production. Univ. of British Columbia, Vancouver, B.C. 3 February, 1994.

27. *"Global Climate Change and Possible Salmon Abundance and Distribution Changes."* Japan-Canada Workshop on Pacific Salmon Production. Cowichan Bay, B.C. 9 February, 1994.

28. *"Growth Variation and Population Dynamics of Salmonids in the North Pacific Ocean".* Third Annual General Meeting, PICES (North Pacific Marine Science Organization), 20 October, 1994.

29. *"Oceanographic Controls and Seasonal Variation in the Oceanic Distribution of Pacific Salmon: Results of the 1992 Canada-Japan Research Program, and Some Implications for Ocean Carrying Capacity."* Oceanography Department, University of British Columbia, Vancouver, B.C. 8 November, 1994.

30. *"Progress on Integrated Harvest Rate Management Modelling."* Fraser River

Action Plan, Science Seminar. Vancouver, B.C. 15 March, 1995.

31. *"Potential Effects on Salmon Production of Interannual Changes in North Pacific Thermal Habitat*" Univ. of British Columbia, Fisheries Center, Fisheries Workshop, March 3, 1995.

32. *"Oceanographic Controls on the Distribution of Pacific Salmon and Possible Impacts of Future Climate Changes on Salmon Production"* XVIII Pacific Science Congress, Beijing, China. 8 June 1995.

33. *"Evolutionary Evidence for a Finite Marine Carrying Capacity for Salmonids".* **(Invited Lecture)** Fourth Annual General Meeting, PICES (North Pacific Marine Science Organization; Science Board Session), Qingdao, China. 16 October, 1995.

34. *"Density-dependent Regulation of Marine Growth in British Columbia Pacific Salmon".* Fourth Annual General Meeting, PICES (North Pacific Marine Science Organization), Qingdao, China. 17 October, 1995. (Science Board Session).

35. *"Thermal Limits and Oceanic Migrations of Pacific Salmon".* Second Korea-Canada Symposium on Marine Environment and Marine Resources. 24 October, 1995. Pusan, South Korea.

36. *"Oceanographic Controls on the Distribution of Pacific Salmon and Possible Impacts of Future Climate Changes on Salmon Production".* Institute of Oceanographic Sciences, Sydney, B.C. 29 February 1996.

37. *"Ocean Temperatures and Distribution of Steelhead Salmon".* **(Invited Speaker)**. Pacific Coast Steelhead Management Meeting, Portland, Oregon. 7 March 1996.

38. *"Growth and Energetics".* **(Invited Speaker)**. Workshop on Estuarine and Ocean Survival of Pacific Salmonids, Newport Oregon 21 March 1996.

39. *"Thermal Limits and Ocean Migrations of Pacific Salmon: Long-Term Consequences of Global Warming".* Sustainable Fisheries Conference, Victoria, B.C. 29 April, 1996.

40. *"Oceanographic and Meteorological Evidence for a Climate Shift in 1990, and the Response of Salmon and Groundfish Resources".* B.C. Ministry of Agriculture, Food, and Fisheries, Victoria, B.C. 15 May, 1996.

41. *"Oceanographic and Meteorological Evidence for a Climate Shift in 1990, and the Response of Salmon and Groundfish Resources".* Fisheries Council of British Columbia, Vancouver. 16 July, 1996.

42. *"Application of acoustic and archival (data storage) tags to studies of salmonid movements in offshore and open ocean systems"* **(Invited Speaker).** NMFS Archival Tag Workshop: Application of acoustic tags and archival tags to assess estuarine, nearshore, and offshore habitat utilization and movement by salmonids, Sept. 10-11/1996, Seattle, Washington.

43. *"New Developments in Geoposition Techniques, and an Evaluation of the Geoposition Accuracy of "Smart" Tags".* **(Invited Speaker).** NMFS Archival Tag Workshop: Application of acoustic tags and archival tags to assess estuarine, nearshore, and offshore habitat utilization and movement by salmonids, Sept. 10-11/1996, Seattle, Washington.

44. *"Thermal Limits and Ocean Migrations of Pacific Salmon: Long-Term Consequences of Global Warming".* Dept. of Zoology, University of Toronto, 23 September 1996.

45. *"Patterns of Scale Growth in B.C. Pacific Salmon, and their Relevance to the "Climate Change and Carrying Capacity" Problem".* Fifth Annual General Meeting, PICES (North Pacific Marine Science Organization), Nanaimo, Canada. (Science Board Session). 18 October, 1996.

46. *"Oceanographic Controls on the Distribution of Steelhead Trout (Oncorhynchus mykiss)".* North Pacific Anadromous fish Commission First International Symposium, "Assessment and Status of Pacific Rim Salmonid Stocks", Sapporo, Japan. 28 October, 1996.

47. *"Geographic and Temporal Patterns of Change in the Marine Survival of British Columbia Salmon-- Why is Our Ocean Changing?"* Inst. of Ocean Sciences, Sydney, B.C. 30 January, 1997.

48. *"Fish Predation on Coelenterates."* (**Invited Speakers**, Joint by Arai, M.N., and D.W. Welch). American Society of Limnology and Oceanography Annual Meeting, Santa Fe, New Mexico, February 12, 1997.

49. *"Current Research on Salmon Archaeology"* (**Invited)**, Archaeological Society of British Columbia, Nanaimo, 9 May, 1997**.**

50. "Changes Associated with the 1989-90 Ocean Climate Shift, and Effects on

British Columbia Steelhead & Coho Salmon Populations". 1997 PICES Annual Meeting, Pusan Korea. 23 October 1997.

51. *"Thermal Limits and Ocean Migrations of Pacific Salmon: Long-Term Consequences of Global Warming*". (**Guest Lecture)** 1997 Annual Meeting of the American Fisheries Society, Alaska Chapter; Juneau, Alaska, 18 November 1997.

52. Ward, B.R., and D.W. Welch. 1997. *"Effects of the 1990 ocean climate shift on trout and salmon".* Presented at the Squamish River Watershed Fisheries Sustainability Forum, Nov. 27-30, 1997, Squamish, B.C.

53. "Changes Associated with the 1989-90 Ocean Climate Shift, and Effects on British Columbia Steelhead & Coho Salmon Populations". 1997 Annual Meeting of the American Fisheries Society, Alaska Chapter; Juneau, Alaska, 19 November 1997.

54. *"Ocean Survival of Steelhead*". **Invited Expert.** Vancouver Island Steelhead Workshop, 8 November 1997.

55. *"The 1989-90 Ocean Climate Shift: Effects on British Columbia Steelhead & Coho Salmon".* Invited participant, 'Aha Huliko'a Hawaiian Winter Workshop on "Biotic Impacts of Extratropical Climate Change in the Pacific", University of Hawaii at Manoa, January 27, 1998.

56. *"Are Their Enough Salmon to Limit Their Own Abundance?*". Invited participant, 'Aha Huliko'a Hawaiian Winter Workshop on "Biotic Impacts of Extratropical Climate Change in the Pacific", University of Hawaii at Manoa, January 29, 1998.

57. *"The 1989-90 Ocean Climate Shift: Effects on British Columbia Steelhead & Coho Salmon".* Fisheries Institute, University of British Columbia, February 23, 1998.

58. *"DFO's High Seas Salmon Research Program: Progress & Findings".* ***Invited Guest Lecture***, Annual General Meeting of the British Columbia Ministry of Environment. 25 March 1998

59. *"Influence of the 1990 Ocean Climate Shift on British Columbia Steelhead (O. mykiss) and Coho (O. kisutch) Populations".* North Pac. Anadr. Fish Commission Symposium. Vancouver, B.C. 26 March 1998.

60. *"DFO's High Seas Salmon Research Program: Progress & Findings"*. Presentation to Nanaimo Chapter of Trout Unlimited. 8 April 1998

61. *"Potential Impacts of Global Warming on British Columbia's Salmon Stocks"*. Presentation to the Department of Environment, Workshop on Uses of Canadian Climate Centre's GCM. Montreal Quebec. 21 April 1998.

62. *"Recent Trends in Ocean Productivity of British Columbia Pacific Salmon".* British Columbia Ministry of Environment, Lands, and Parks, Victoria B.C. *15 May 1998.*

63. *"Thermal Limits and Ocean Migrations of Pacific Salmon: Long-Term Consequences of Global Warming*". (**Invited Presentation**). Ministry of Agriculture, Food, and Fisheries, Lowestoft, U.K. *19 May 1998.*

64. *"Ocean Migration Pathways of Juvenile Pacific Salmon".* Ministry of Agriculture, Food, and Fisheries, Lowestoft, U.K. *20 May 1998.*

65. *"Ocean Ecology of Pacific Salmon and Effects of a Climate Shift in the 1990s on North American Salmon Production".* Presentation to new Canadian negotiator for Canada-US Salmon Treaty and Assistant Deputy Minister (Fisheries Management). Vancouver, B.C. 5 August 1998.

66. *"Implications of climate change projections for salmon in the North Pacific".* ***Invited Lecture***, l'Institut Maurice-Lamontagne à Mont-Joli. Mont-Joli, Quebec. 17 September 1998

67. *"Impacts of the recent and past El Niño events on nutrient supply, primary production and plankton distribution off the B.C. coast".* Frank Whitney, David Mackas, David Welch and Marie Robert. PICES 7th Annual Meeting, Fairbanks, Alaska. October 1998

68. *"Ocean Climate Change and Population Dynamics of British Columbia Salmon in the 1990s".* ***Invited Lecture***, Hatfield Marine Science Center, Newport, Oregon, 27 January, 1999.

69. *"Changing Ocean Climate and Impacts on Pacific Salmon Populations".* ***Invited Presentation***, Bonneville Power Authority, Policy & Planning Group, Portland, Oregon. 29 January 1999.

70. *"Projected Impacts of Global Warming on North Pacific Salmonids*". (**Invited as Expert Member)** Global Climate Change and Marine Biodiversity, Expert Meeting convened by the Marine Conservation Biology Institute

and World Wildlife Fund, Washington D.C. Feb 1-3, 1999.

71. *"Ocean Climate Change and Status of British Columbia Salmon in the 1990s".* American Fisheries Society, North Pacific Chapter Annual General Meeting, Vancouver, B.C., 16 February 1999.

72. *"Oceans, Oceanography, and the Future of West Coast Salmon".* ***(Invited Keynote Lecture)*** Annual General Meeting of Northern British Columbia and Yukon Biologists, 26 February, 1999.

73. *"Ocean Processes and Salmon Ecology Short Course".* (Invited Two Day Short Course, taught jointly with Prof. Tom Royer, "Eminent Professor & Samuel L. and Fay M. Slover Chair of Physical Oceanography, Old Dominion University) Alaska Dept. of Fish & Game. 8-9 March 1999, Anchorage Alaska.

74. *"Changing Ocean Climate and Impacts on Pacific Salmon Populations".* ***Invited Presentation***, Northwest Power Planning Council, Boise, Idaho. 6 April 1999.

75. North Pacific Salmon Workshop. Corvallis, Oregon. 4-5 May 1999.

76. "*Impacts of Recent & Future Climatic Change on the West Coast Salmon Resource*". Environment Canada, Climate Change Impacts Assessment Workshop. Montréal Quebec 28 May 1999.

77. "*Evidence for Changed Ocean Productivity and Impacts on Pacific salmon Growth & Survival*". GLOBEC Canada, National Workshop. Halifax, Nova Scotia 28 May 1999.

78. *"Global Warming and Anticipated Effects on Marine Life."* **Invited Speaker** (one of two scientific experts) to lead a "Press Backgrounder" for the World Wildlife Fund on Oceans Day. 8 June 1999, National Press Club, Washington D.C.

79. *"Testimony to the Committee on Energy & Natural Resources, United States Senate".* **Invited** . United States Senate, Energy and Natural Resources Oversight Committee, Washington, D.C. 9 June 1999.

80. "*Evaluation of attachment techniques and geoposition accuracy of archival tags for studying the migration of salmon at sea*". J.P. Eveson & D.W. Welch ***(Atlantic Salmon Trust Sponsored Presentation).*** Third Conference on Fish Telemetry in Europe. Norwich, U.K. 21 June 1999.

81. "*Data Storage Tag study of Salmon (Salmo salar) Migration in the Baltic: The performance of tags*". Håkan Westerberg, Paige Eveson, David Welch, L. Karlsson, and E. Ikonen. ICES Annual Conference, Stockholm, Sweden. September 1999.

82. "*Geolocation Using Light: Effects of Depth*". Paige Eveson and David Welch. ICES Annual Conference, Stockholm, Sweden. September 1999.

83. "*Climate Change & Ocean Survival of Pacific Salmon".* David Welch, Frank Whitney, and Doug Bertram. ***(Invited Presentation)*** PICES VIII Annual Meeting, Vladivostok, Russia. October 1999.

84. *"Canadian GLOBEC Studies and their Contributions to Management of Marine Living Resources". R. Ian Perry, David L. Mackas, and David W. Welch* PICES VIII Annual Meeting, Vladivostok, Russia. October 1999.

85. *"Probable Impacts Of Global Warming And Climate Change On B.C. Salmon Resources". PFRCC (Pacific Fisheries Resource Conservation Council). Vancouver, 27 October 1999.* **(Invited).**

86. *"Climate Change, Global Warming, & Effects on Pacific Salmon". JISAO/SMA Climate Impacts Group, University of Washington. Seattle, Wash.*. 4 November 1999. **(Invited).**

87. *"Effect of Ocean Climatic Shifts on Growth and Survival of Endangered Salmon Stocks".* Bonneville Power Administration, Portland, Oregon. 22 November 1999

88. "*After the Ice Age: Post-glacial dispersal, salmon genetics, and the decline of BC salmon fisheries: Why the Oceans are doing it ".* Inst. Of Ocean Sciences, Sidney B.C. 7 January, 2000.

89. "*Climate Change, Global Warming, and the Challenge for the Department".* Fisheries & Oceans Canada West Coast Science Meeting, Parksville, B.C. 12 January, 2000.

90. "*Ocean conditions and survival trends for BC salmon and steelhead". B.C. Ministry of Environment, Lands and Parks, Nanaimo, B.C., January 15, 2000.* **(Invited).**

91. *"Climate Change, Global Warming, & The PICES 4C's Program for Improved Monitoring".* Exxon Valdez Oil Spill Trustee Council, Restoration

Workshop: "Applying Science to Human Needs: Starting the Transition to the Gulf Ecosystem Monitoring (GEM) Program". 18 January, 2000. Anchorage, Alaska. **(Invited Plenary Address).**

92. *"Ocean Climate Change and the Management of Endangered Pacific Salmon Stocks". National Marine Fisheries Service, Seattle, Washington.* 19 January, 2000.

93. "*Ocean Climate Effects on Pacific Salmon".* Bonneville Power Administration Presentation to C.E.O. & Senior Executive. 3 February 2000, Portland, Oregon **(Invited)**

94. "*Climate Change, Global Warming, & Effects on Pacific Salmon*". Dept of Zoology, University of British Columbia **(Invited)** March, 2000.

95. *"Ocean Climate Change and the Management of Endangered Pacific Salmon Stocks".* University of Victoria, Victoria B.C. 3 March 2000.

96. "*Ocean Climate Effects on Pacific Salmon". House Resource and Conservation Committee,* Idaho State Legislature, Boise, Idaho 13 March 2000 **(Invited)**

97. "*Ocean Climate Effects on Pacific Salmon". American Fisheries Society,* Idaho Chapter, Couer D'Alene, Idaho 14 March 2000

98. "*Ocean Climate Effects on Pacific Salmon".* Northwest Power Planning Council, Pasco, Idaho. 15 March 2000 **(Invited)**

99. *"Global Warming and the Future of Canada's Pacific Salmon Resources".* Vancouver Public Aquarium, Hot Topics Series. 15 March 2000 **(Invited)**

100. "*Climate Impacts on Wild Fisheries*". Seafood Sustainability in a Changing Climate; Northeast Pacific Ocean and Coastal Zones. May 25-26, 2000 University of Victoria, Victoria, BC **(Invited)**

101. *"Ocean Effects on Pacific Salmon".* Practical Paths to Salmon Recovery. Idaho Council on Industry and the Environment. Boise, Idaho. 26 September 2000. **(Invited)**

102. "*Predation by fish, especially chum salmon, on North Pacific coelenterates*". M. N. Arai, K. Nagasawa, and D.W. Welch. PICES IX, Hakodate, Japan. October 2000

103. *"Stock separation and environmental changes in chum salmon habitats using stable isotope contents in otoliths"* Suam Kim, Sukyung Kang, David Welch, Jack Helle, and Kazuya Nagasawa. PICES IX, Hakodate, Japan. October 2000

104. *"Chikyu Ondanka to Sakana no Minshu".* Public Lecture, Hakodate Japan. 25 October, 2000 **(Invited)**

105. *"Ocean Migrations of Pacific Salmon & Possible Impacts of Climate Change".* Stanford University. 18 January, 2001. **(Invited)**

106. *"Ocean Climate and the Future of Pacific Salmon- or how Fisheries Effects Became More Important than they Really Should Be".* 29 March, 2001. ***(21st* Century Lecture; Invited)** Inst. of Ocean Sciences, Sydney, British Columbia.

107. *"POST & The Census of Marine Life Initiative".* Environmental Sensor Array (ESA) CFI Workshop. University of British Columbia, Vancouver. April 9, 2001.

108. *"POST & The Census of Marine Life Initiative".* Presentation to the Honourable John Fraser, Chairman, Pacific Fisheries Resource Conservation Council. Vancouver, B.C. 17 April, 2001.

109. *"A Riddle Wrapped in a Mystery inside an Enigma: Tracking the Ocean Migration of Pacific Salmon".* Hot Topics Lecture, Vancouver Aquarium & Marine Science Society. 24 April, 2001. Vancouver, B.C. **(Invited).**

110. *"The Pacific "Anadrobahn"- A Coastal Migration Pathway For Juvenile Salmon Migrations, And Relevance To The Proposed Census Of Marine Life Program "**POST**".* Fourth Conference in Telemetry in Europe, Trondheim, Norway. 26-30 June 2001.

111. *"POST"-The Census of Marine Life initiative to develop a Pacific Ocean Salmon Tracking Program.* PICES X, Victoria, B.C. 11 October, 2001.

112. *"Changes in water masses, nutrients, chlorophyll, & zooplankton across juvenile salmon habitat on the continental shelf during the 1998/1999 shift from warm-ocean to cool-ocean conditions".* J.E. Zamon, F.A. Whitney, D.W. Welch, M. Robert, J. Morris, M. Trudel, and M.E. Thiess. (Poster Presentation). PICES X, Victoria, B.C. October, 2001.

113. *"Are salmon starving in the ocean?".* M. Trudel, S. Tucker, and D.W. Welch. (Poster Presentation). PICES X, Victoria, B.C. October, 2001.

114. "*A Comparison of Projected Climate Change Scenarios on Ocean Distributions of Pacific Salmon".* Canadian Conference for Fisheries Research. Vancouver, B.C. Jan 4, 2002. **(Invited)**.

115. *"Are salmon starving in the ocean?".* M. Trudel, S. Tucker, and D.W. Welch. Canadian Conference for Fisheries Research. Vancouver, B.C. Jan 4, 2002.

116. *"Flip, Flop And Fry: Climate-Induced Variation In Keogh River Salmonid Carrying Capacity And Survival In The Ocean".* Ward, B.R. D.J.F. McCubbing, and D.W. Welch. Canadian Conference for Fisheries Research. Vancouver, B.C. Jan 4, 2002.

117. *"Electronic Tagging of Pelagic Species in the Census of Marine Life".* G.W. Boehlert, B.A. Block, D.W. Welch, D.P. Costa, & R. Kochevar. AGU/ASLO Ocean Science Meeting, Honolulu, Hawaii. 5 February 2002

118. *"Ocean Climate Change and Pacific Salmon Migrations".* Dept. of Biology, Memorial University. St John's, Newfoundland. 4 February, 2002. **(Invited).**

119. *"**POST**-The Pacific Ocean Salmon Tracking Project".* American Association for the Advancement of Science Annual Meeting, 17 February, 2002. Boston, Mass. **(Invited).**

120. *"Influence of Ocean Conditions on Columbia River Salmon Populations".* Corps of Engineers Spring Planning Meeting, Stevenson Washington. 18 February 2002, **(Invited).**

121. *"Latitudinal and Temporal Gradients in Ocean Productivity and Survival of Salmon".* Toward Ecosystem-Based Management: Breaking Down the Barriers in the Columbia River Basin and Beyond. Spokane, Wash. xx April 2002.

122. *POST- An Acoustic Tracking Array for the West Coast of North America.* Toward Ecosystem-Based Management: Breaking Down the Barriers in the Columbia River Basin and Beyond. Spokane, Wash. xx April 2002. **(Invited).**

123. *"Potential Interrelationships between Patterns of Migration and Marine Survival in Pacific Salmon".* Joint Meeting of Causes of marine mortality of

Salmon in the North Pacific and North Atlantic Oceans and in the Baltic Sea. Vancouver, B.C. 14 March 2002.

124. *"Latitudinal And Temporal Gradients In Ocean Productivity & Survival Of Salmon".* American Society for Limnology and Oceanography, Victoria, B.C. xx June, 2002.

125. *"Shift Happened: Changes In Plankton Community Structure On The British Columbia Continental Shelf During 1998-1999".* American Society for Limnology and Oceanography, Victoria, B.C. xx June, 2002.

126. *"Progress on developing a continent scale acoustic array for tracking marine fish"* III Coloquium on Oceanography of the Eastern Pacific. 11-13 September 2002. Ensenada, Mexico. **(Invited)**

E.INTERNATIONAL COMMISSIONS

1. **North Pacific Marine Science Organization (PICES)**.

Canadian member, Working Group 6, Subarctic Gyre. 1993-94. (WG6 disbanded Nov. 94)

Canadian Member, Working Group 9, Subarctic Pacific Monitoring, 1995-97 (WG9 disbanded Nov. 97).

Canadian Member, Monitoring Task Team, 1998- .

PICES-GLOBEC Chairman, CCCC-IP (Carrying Capacity and Climate Change Implementation Plan) 1998-2000 (3 year term).

Chairman, CPR Monitoring Advisory Committee, 1999- .

2. **North Pacific Anadromous Fish Commission,** *Canadian Member*, Committee on Scientific Research and Statistics, *1993 - . Chair,* NPAFC Archival Tag Working Group. 1998-

3. **North Pacific Anadromous Fish Commission,** *Chairman,* Statistical Yearbook Working Group. *1993 - 1996.*

4. **INPATE,** *Chairman,* International North Pacific Archival Tag Evaluation Working Group. *1996-*

5. **ICES Study Group on Ocean Salmon Tagging Experiments with Data Logging Tags.** *Canadian Member, February 1997 -*

6. **North Pacific Anadromous Fish Commission.** *March 1995 - 1997*. Working Group on Salmon Stock Identification and Growth. *Canadian Member.*

7. **International North Pacific Fisheries Commission,** *Canadian Member* to Salmon SubCommittee, *1990, 1991, & 1992. Advisor*, Canadian Delegation to Salmon SubCommittee, *1988-1989.*

8. **Canada-USSR Joint Scientific and Industry Bilateral Meetings.** June, *1990.* Yuzhno-Sakhalinsk, USSR.

9. **United Nations Scientific Review Meeting of North Pacific High Seas Driftnet Fisheries**. *June 11-14, 1991. Canadian Member*, Squid and Salmonid Fishes Working Group. *Chairman,* Non-Salmonid Fishes and Marine Turtles Working Group.

10. **Second Korea-Canada Symposium on Marine Environment and Marine Resources.** 23-25 October, 1995. Pusan, South Korea. *Canadian Member.*

F.NATIONAL & REGIONAL COMMITTEES

1. **Pacific Stock Assessment Review Committee (PSARC).** Chairman, Groundfish Subcommittee, 1997 - 1999. Member, PSARC Steering Committee, 1997- 1999. Member, Fisheries Oceanography Working Group 1999 - .

2. **NSERC External Review Meeting, for joint DFO-NSERC GLOBEC-CANADA proposal, Montreal, Quebec.** Pacific Regional Representative. May 23-24, 1996.

3. **Pacific Stock Assessment Review Committee (PSARC).** Chairman, Data and Systems Subcommittee, 1993 -1995 . Member, PSARC Steering Committee, 1993- 1995.

4. **Pacific Biological Station, DFO**. Site Committee. 1995 -

5. **Pacific Biological Station, DFO**. Research Vessel Committee. 1995 -

6. **DFO Pacific Science Working Group,** "Conservation Risks from Ocean Climate Changes". Member, 1995 -

7. **Fraser River Task Force,** Integrated Salmon Production and Management Plan Chairman, Technical Working Group. 1993 - 1995.

8. **Cyclic Dominance Working Group,** reporting to Fraser Task Force on scientific issues involving sockeye rebuilding. Member, 1988-90.

9. **West Coast Vancouver Island & Georgia Strait Chinook Model Review Committee.** Member, 1989.

F.EXTERNAL ACTIVITIES AND CONSULTANCIES

1. **Editorial Advisor.** Marine Ecology Progress Series. Editorial Advisor in the area of mathematical and statistical modelling, and population dynamics. (1991-93).

2. **Scientific Advisor and Consultant.** Oregon State Dept. of Fish and Wildlife, Clackamas, Oregon. 1990, 1991, 1992, & 1993. Technical advice and interpretation on methods of analysis of Columbia River white sturgeon maturation, applying and adapting statistical and mathematical methods developed by myself for use on other fish species to white sturgeon population biology.

3. **Associate Editor.** Proceedings of the International Workshop on Future Salmon Research in the North Pacific Ocean, Shimizu, Japan. Special Publication of the National Research Institute of Far Seas Fisheries No. 20. (1992).

4. **Senior Editor.** "Assessment and Status of Pacific Rim Salmonid Stocks". (With D. M. Eggers, K. Wakabayashi, and V. I. Karpenko (Editors), N. Pac. Anadr. Fish Comm. Bull. No. 1, 513 pp. (1998)

5. **Chairman,** INPATE, (International North Pacific Archival Tag Assessment Evaluation Working Group). 1996-

6. **Canadian Co-Principal Investigator**. IAI Proposal: Comparative studies of temperate aquatic ecosystems using Pacific salmon as an indicator of global change and changing land use: Boreal and Austral Salmon Collaborative Research Network. (BASCRN)

7. **Session Convenor.** "Effects of Ocean Change on Salmon Survival", 1999 Annual General Meeting of the American Fisheries Society, North Pacific International Chapter, Richmond B.C. 16 Feb, 1999.

8. **Lecturer, Professional Development.** Invited by the Alaska Department of Fish and Game to Present a two day series of lectures on the issue of current biological information on effects of climatic change on salmon production in the ocean, and the effects of oceanographic change on salmon (March 1999). This seminar series was prepared for presentation to ca. 200 of Alaska's professional state biologists. (Joint with Prof. Tom Royer of Old Dominion University, a physical oceanographer)

9. Session Co-Chair. PICES Conference: "*Beyond El Nino: A Conference on Pacific Climate Variability and Marine Ecosystem Impacts, from the Tropics to the Arctic". La Jolla, California. 23-26 March* 2000.

10. **Session Convenor.** "Beyond El Nino" Conference. La Jolla, San Diego. 27 March 2000.

11. **Session Co-ordinator.** "Climate Change Impacts on British Columbia Salmon". Halifax, Nova Scotia. 2 May 2000.

12. **Session Co-Convenor,** PICES IX Conference: "Recent progress in zooplankton ecology study in PICES regions". Hakodate, Japan. October, 2000.

13. **Program Advisor,** Alaska Salmonid Biodiversity Program, Trout Unlimited. 1999 –

14. **Organizing Committee.** NPAFC/PICES International Workshop "*Factors Affecting Production of Juvenile Salmon: Comparative Studies on Juvenile Salmon Ecology between the East and West North Pacific Ocean*" Oct. 29, 2000 Tokyo, Japan.

15. **US-GLOBEC, NE Pacific Review Panel.** National Science Foundation-NOAA. Washington D.C., 24-26 July, 2000

16. **Scientific Advisory Committee.** Second Symposium on Marine Conservation Biology, San Francisco State University, July 2000–.

17. **Scientific Steering Committee.** Development of a Geolocation Data Storage Tag for Open Ocean Tracking of Atlantic Salmon. Co-sponsored by Canadian Ocean Technology Fund & LOTEK Wireless Inc.

18. **Census of Marine Life.** Organised Workshop *"Use of Electronic Tags for Tracking Pacific Salmon"*. 8-9 December, Vancouver, British Columbia.

19. **Census of Marine Life.** Developed Planning Proposal "***POST****–the Pacific Ocean Salmon Tracking Project*", at the Request of the Scientific Steering Committee for the Sloan Foundation's Census of Marine Life.

20. **Scientific Organizing Committee**, NPAFC-NASCO-IBSFC joint meeting on "*Causes of Marine Mortality of Salmon in the North Pacific and North Atlantic Oceans and in the Baltic Sea*". Vancouver, 14-15 March 2002.

21. **Organizing Committee.** PICES X Annual General Meeting. Victoria, British Columbia.

22. **Co-Convenor.** PICES X Anniversary Symposium. *"Ten years of PICES science: Decadal-scale scientific progress and prognosis for a regime shift in scientific approach".* 8 October, 2001. Victoria, British Columbia.

23. **Session Convenor.** X

24. **Session Convenor.** American Society for Limnology and Oceanography annual meeting.

G. PEER REVIEWED JOURNAL ARTICLES

1. ***Welch, D.W.*** 1986. Identifying the Stock-Recruitment Relationship for Age-Structured Populations Using Time-Invariant Matched Linear Filters. Can. J. Fish. Aquat. Sci. 43(1):108-123.

2. ***Welch, D.W.*** 1987. Frequency-domain Filtering of Age-Structured Population Data. Can. J. Fish. Aquat. Sci. 44(3): 605-618. *Erratum: Can. J. Fish. Aquat. Sci. 45:383 (1988).*

3. ***Welch, D.W.*** 1987. Use and Precision of Age-structure Based Filtering Theory. Can. J. Fish. Aquat. Sci. 44(3): 692-694.

4. ***Welch, D.W.*** 1987. Influence of Three Life History Strategies on the Information Content of Stock-Recruitment Data. Can. J. Fish. Aquat. Sci. 44(7):1375-1379.

5. **Noakes, D.J., *D.W. Welch*, and M. Stocker.** 1987. A Time Series Approach to Stock-Recruitment Analysis: Transfer Function Noise Modelling. Natural Resource Modeling 2(2):213-233.

6. ***Welch, D.W.*** **and R.P. Foucher.** 1988. A Maximum Likelihood Methodology for Estimating Length-at-Maturity with Application to Pacific Cod (*Gadus macrocephalus*) Population Dynamics. Can. J. Fish. Aquat. Sci. 45(2): 333-343.

7. **Noakes, D.J., *D.W. Welch*, M. Henderson, and E. Mansfield.** 1990. A Comparison of Preseason Forecasting Methods for Two British Columbia Sockeye Salmon Stocks. N. American J. Fisheries Management. 10(1): 46-57.

8. ***Welch, D.W.*** **and G.A. McFarlane.** 1990. Quantifying the Growth of Female Pacific Hake (*Merluccius productus*): An Example of Measuring Uncertainty and Bias in Non-linear Parameter Estimation. Can. J. Fish. Aquat. Sci. 47(4): 672-681.

9. ***Welch, D.W.*** **and D.J. Noakes.** 1990. Cyclic Dominance and Optimal Escapement of Adams River Sockeye (*Oncorhynchus nerka*). Can. J. Fish. Aquat. Sci. 47(4): 838-849.

10. ***Welch, D.W.*** **and D.J. Noakes.** 1991. Optimal Harvest Rate Policies for Rebuilding the Adams River Sockeye, *Oncorhynchus nerka*. Can. J. Fish. Aquat. Sci. 48(4): 526-535.

11. ***Welch, D.W.*, L. Margolis, M.A. Henderson, and S. McKinnell.** 1991. Evidence for Attacks by the Bathypelagic Fish *Anotopterus pharao* (Myctophiformes) on Pacific Salmon (*Oncorhynchus* spp.). Can. J. Fish. Aquat. Sci. 48:2403-2407.

12. ***Welch, D.W.* and J.F.T. Morris.** 1993. Age and Growth of Flying Squid (*Ommastrephes bartrami*). p. 183-190 *in:* International North Pacific Fisheries Commission Bull. No. 53. Symposium on Biology, Distribution and Stock Assessment of Species Caught in the High Seas Driftnet Fisheries in the North Pacific Ocean. (II) Oceanography - Biology - Ecology (All Species).

13. ***Welch, D.W.* and Y. Ishida.** 1993. On the statistical distribution of salmon in the sea: Application of the negative binomial distribution, and the influence of sampling effort. Can. J. Fish. Aquat. Sci. 50(5):1029-1038

14. ***Welch*, *D.W.*, and T.R. Parsons.** *1993.* $\delta^{13}C - \delta^{15}N$ anomalies as indicators of relative trophic position for Pacific salmon (*Oncorhynchus* spp.). *Fish Oceanogr.* 2:11-23.

15. ***Welch*, *D.W.*** *1993.* Phytoplankton Productivity? *Nature* 362:795-796

16. **Ishida, Y., *D.W. Welch*, and M. Ogura.** *1995.* Potential influence of North Pacific sea-surface temperatures on increased production of chum salmon (Oncorhynchus keta) from Japan. p. 271-275. *In* R.J. Beamish [ed.] Climate Change and Northern Fish Populations. Can. Spec. Publ. Fish. Aquat. Sci. No. 121.

17. ***Welch*, *D.W.*, A.I. Chigirinsky, and Y. Ishida.** 1995. Upper Thermal Limits on the Oceanic Distribution of Pacific Salmon (*Oncorhynchus* spp.) in the Spring. Can. J. Fish. Aquat. Sci. 52(3):489-503

18. ***Welch*, *D.W.*** *1995.* First record of offshore spawning for the Black Rockfish, *Sebastes melanops*. Can. Field Nat. 109(4):477-479.

19. **Everett, J.T., E. Okemwa, H.A. Regier, J.P. Troadec, A. Krovnin, and D. Lluch-Belda, *(Lead authors, plus 26 co-authors including D.W. Welch)*.** *1996.* Fisheries. *In:* Climate Change 1995: Impacts, Adaptations and Mitigation of Climate Change: Scientific-Technical Analyses. Contribution of Working Group II to the Second Assessment Report of the Intergovernmental Panel on Climate

Change. [Watson, R.T., M.C. Zinyowera, and R.H. Moss (eds.)]. Cambridge University Press, Cambridge and New York, 880 p.

20. *Welch*, *D.W.*, and J.N. Till. 1996. First record of a chum salmon (*Oncorhynchus keta)* from the Thompson River: Adams river spawning grounds, British Columbia. Can. Field Nat. 110(2):332-334.

21. Bigler, B.S., *D.W. Welch*, and J.H. Helle. *1996.* A review of size trends among North Pacific salmon (*Oncorhynchus* spp.). Can. J. Fish. Aquat. Sci. 53:455-465.

22. *Welch*, *D.W.* *1997.* Anatomical differences in the gut structure of Pacific salmon (*Oncorhynchus*): Evidence for oceanic limits to salmon production? Can. J. Zoology 75(6):936-942.

23. *Welch, D.W*. *1997.* Obituary-- Leo Margolis, O.C., Ph.D., F.R.S.C. Can. J. Fisheries and Aquatic Sciences. 54:1682-1684

24. *Welch, D.W.,* Y. Ishida, and K. Nagasawa. *1998.* Thermal Limits and Ocean Migrations of Sockeye Salmon (*Oncorhynchus nerka*): Long-Term Consequences of Global Warming. Can. J. Fish. Aquat. Sci. 55:937-948. (*For a commentary on this paper, see Science 280:1349, 29 May 1998 issue).*

25. *Welch, D.W.,* Y. Ishida, K. Nagasawa, and J.P. Eveson. *1998.* Thermal Limits On The Ocean Distribution Of Steelhead Trout (*Oncorhynchus mykiss*). *In:* D.W. Welch, D.M. Eggers, K. Wakabayashi, and V.I. Karpenko (*Editors*), *"Assessment and Status of Pacific Rim Salmonid Stocks".* N. Pac. Anadr. Fish Comm. Bull. No. 1:396-404.

26. S.M. Bower, J. Blackbourn, G.R. Meyer, and *D.W. Welch*. *(1999).* Effect of *Perkinsus qugwadi* on various species and strains of scallops. Diseases of Aquatic Organisms. 36:143-151

27*. *Welch, D.W., and J.P. Eveson. *1999.* An assessment of the geoposition accuracy of data storage (archival) tags using light. Can. J. Fish. Aquat. Sci. 56(7):1317-1327

28*. *Welch, D.W. *1999.* New Developments in Ocean Salmon Research. *EEZ Technology* 4:203-210.

29. Smith, B.D., B.R. Ward, and ***D.W.Welch.*** *2000.* Trends in wild adult steelhead (*Oncorhynchus mykiss*) abundance in British Columbia as

indexed by angler success. Can. J. Fish. Aquat. Sci. 57:255-270

30. ***Welch, D.W.***, B.R. Ward, B.D. Smith, and J.P. Eveson. 2000. Temporal and Spatial Responses of British Columbia Steelhead (*Oncorhynchus mykiss*) Populations to Ocean Climate Shifts. Fisheries Oceanography 9(1):17-32.

31. Eveson, J.P., and ***D.W. Welch.***. *2000*. "*Evaluation of techniques for attaching archival tags to Salmon: Influence on growth and survival".* Fish Telemetry: Proceedings of the 3rd Conference on Fish Telemetry in Europe (Edited by A. Moore and I. Russell). p. 29-35.

32. Bugaev, V. F., ***D.W. Welch***, M. M. Selifonov, L. E. Grachev, and J.P. Eveson. (*2001*) Influence of the Marine Abundance of Pink (*Oncorhynchus gorbuscha*) and Sockeye Salmon (*O. nerka*) on Growth of Ozernaya River Sockeye. Fisheries Oceanography. 10(1):26-32.

33. ***Welch*, *D.W.*,** and P.M. Pankhurst. (*2001).* Visual morphology and feeding behaviour of the daggertooth (*Anotopterus nikparini*). J. Fish Biology 58(5):1427-1437.

34. ***Welch*, *D.W.*** *(2001).* Fisheries: Pacific Coast Salmon. *In*: *"The Encyclopaedia of Global Environmental Change"*, John Wiley & Sons, Chichester. Vol. 3, P. *xxx*

35. ***Welch, D.W.*** and J.P. Eveson. (2001). Recent Progress in Estimating Geoposition using Daylight. In: Electronic Tagging and Tracking In Marine Fisheries" *In*: Methods and Technologies in Fish Biology and Fisheries, Vol 1. J. Sibert and J. Nielsen (eds.) Kluwer Academic Press, Dordrecht, The Netherlands. p. 369-384.

36. Musyl, M.K. R.W. Brill, D.S. Curran, J.S. Gunn, J.R. Hartog, R.D. Hill, ***D.W. Welch***, J.P. Eveson, C.H. Boggs, and R.E. Brainard (*2001*). Ability of archival tags, submerged at varying depths on a stationary mooring line in the Pacific Ocean, to provide estimates of geographical position based on light intensity. In: Methods and Technologies in Fish Biology and Fisheries, Vol 1. J. Sibert and J. Nielsen (eds.) Kluwer Academic Press, Dordrecht, The Netherlands. p. 343-367.

37. Whitney, F.A. and ***Welch, D.W.*** (*In Press*) Impact of the 1997-8 El Niño and 1999 La Niña on nutrient supply in the Gulf of Alaska. Prog. Oceanogr.

38. McKinnell, S.M., C.C. Wood, D.T. Rutherford, K.D. Hyatt, and ***D.W. Welch.***

(*2001*). The demise of Owikeno Lake sockeye salmon. N. American J. Fish. Manage. 21:774–791.

39. Kim, S., Kang, S., ***Welch, D.W.,*** Helle, J., Nagasawa, K. (*In Press*) Stable Isotope Evidence for Stock Separation and Environmental Characteristics in Chum Salmon Ocean Habitats. *Fisheries Oceanography*

40. ***Welch, D.W.,*** Batten, S.D., and Ward, B.R. (*submitted*) "*Growth, Survival, and Rates of Tag Retention for Surgically Implanted Acoustic Tags in Steelhead Trout (O. mykiss)*". Trans. Am. Fish. Soc.

41. ***Welch, D.W***. (*Submitted*). Global Warming & Contemporary Fisheries Management. Fisheries.

42. ***Welch, D.W.,*** J.P. Eveson, and R.I. Perry (*Submitted*). Patterns of Coherence in Marine Growth of British Columbia Sockeye Salmon (*O. nerka*). *Can J Fish Aquat Sci.*

43. ***Welch, D.W.,*** and P.H. Ostrom. *(in prep).* Influence of Lipid Level on $\delta^{13}C$ and $\delta^{15}N$ Values in Food Web Studies. Marine Ecology Progress Series xx:0000-0000.

44. ***D.W. Welch***, J.P. Eveson, M. Trudel, Y. Ishida, K. Nagasawa (*In Prep*). A Comparison of Projected Climate Change Scenarios on Ocean Distributions of Pacific Salmon.

45. Trudel, M., ***Welch, D.W.,*** Brodeur, R.D., Tadokoro, K., Fukuwaka, M., and Sugimoto, T. A bioenergetic analysis of the thermal limits of sockeye salmon (*Oncorhynchus nerka*). In preparation for Fisheries Oceanography.

46. Beamish, R.J., Pearsall, I.A., ***Welch, D.W.,*** and Levings, C.D. (In prep) *"Studies of the life history of Pacific salmon in their first marine year off Canada's Pacific coast"*. NPAFC Bulletin No 2. In prep.

H SECONDARY PUBLICATIONS

1. ***Welch*, *D.W.* and R.P. Foucher.** 1986. Analysis of Natural Population Regulation in Hecate Strait Pacific Cod. p. 49-50. *in: Tyler, A.V. (ed.) Hecate Strait Project: Results of the first two years of multispecies fisheries research. Can Tech. Rept. Fish. Aquat. Sci. 1470: 50 pp.*

2. **Foucher, R.P. and *D.W.* *Welch*.** 1987. Port Sample and Research Cruise Maturity-at-Length data collected for Female Pacific cod (*Gadus macrocephalus*) from Hecate Strait, 1960-87. *Can. Data Rept. Fish. Aquat. Sci. No. 652: 19 pp.*

3. ***Welch*, *D.W.*** 1987. Efficient Frequency Domain Filtering Algorithm for Small Data Sets. *Can. Tech. Rept. Fish. Aquat. Sci. No. 1559: 27 pp.*

4. **Steer, G.J., N.B.F. Cousens, H.W. Stiff, K.D. Hyatt, and *D.W.* *Welch*.** 1988. A Description of the 1984 Fishery, Stock Composition, and Biological Characteristics of the Sockeye Salmon (*Oncorhynchus nerka*) in the Catch from Area 23, Barkley Sound. *Can. Tech. Rept. Fish. Aquat. Sci. No. 1667, 78 pp.*

5. **Noakes, D.J., *D.W.* *Welch*, M. Henderson, and E. Mansfield.** 1988. An Overview of Alternative Methods for Generating Preseason Forecasts of Pacific Salmon Returns. *PSARC Working Paper S88-19, 61 pp., 3 figs.*

6. ***Welch*, *D.W.*** 1988. Japanese High Seas Salmon Research: Observations made aboard the Kanki Maru No. 3, June 4 - July 6, 1988. 14 p. *(Document submitted to the Annual Meeting of the International North Pacific Fisheries Commission, Tokyo, Japan, November, 1988).* Dept. of Fisheries and Oceans, Pacific Biological Station, Nanaimo, B.C., Canada V9R 5K6

7. ***Welch*, *D.W.*** 1988. Wiener-optimal estimation and the stock I.D. & Age Misclassification Problems. p.114-115 *in: Natural Resource Modelling and Analysis. Proceedings of the First Interdisciplinary Conference on Natural Resource Modelling and Analysis. A. T. Charles and G. N. White III [eds]. Centre for Resource Systems Analysis. ISBN 0-9694196-0-0.*

8. ***Welch*, *D.W.* & R.P. Foucher.** 1989. Influence of Variation in Length-at-maturity on the Population productivity of Pacific cod (*Gadus macrocephalus*). p. 56-57. *Hecate Strait Project: Results of four years of multispecies fisheries research. Can. J. Fish. Aquat. Sci. Tech.*

Rept. No. 1675.

9. ***Welch*, *D.W.* and D.J. Noakes.** 1989. From Data to Indecision: An Evaluation of Optimal Stock Size Strategies for Adams River Sockeye (*Oncorhynchus nerka*). *PSARC Working Paper S89-26. 31 pp. & 7 figs.*

10. ***Welch*, *D.W.* and D.J. Noakes.** 1990. Optimal Harvest Rate Policies for Rebuilding the Adams Sockeye. *PSARC Working Paper S90-33. 25 pp. & 6 figs.*

11. ***Welch*, *D.W.*, T.W. Gjernes, O.A. Rasadnikov, and A. Korolov.** 1990. Upper Thermal Limits on the Late Spring Distribution of Pacific Salmon (Oncorhynchus spp.) in the Northeast Pacific. 17 p. *(Document submitted to the Annual Meeting of the International North Pacific Fisheries Commission, Vancouver, B.C., Canada, November, 1990).* Dept. of Fisheries and Oceans, Pacific Biological Station, Nanaimo, B.C., Canada V9R 5K6

12. ***Welch*, *D.W.*, L. Margolis, and M. Henderson.** 1991. A historical summary and bibliography of Canadian Research Activities using gillnets in the North Pacific Ocean. 19 p. and 8 figs. *(Document submitted to the Scientific Review Meeting on North Pacific High Seas Driftnet Fisheries, Sidney, British Columbia, 11-14 June, 1991, reporting to the United Nations on General Assembly Resolution 44/225).*

13. ***Welch*, *D.W.* and Y. Ishida.** 1991. On some sampling characteristics of high seas gillnet surveys for salmon. *(Document submitted to the Annual Meeting of the International North Pacific Fisheries Commission, Tokyo, Japan, November, 1991, 29 p.).* Dept. of Fisheries and Oceans, Pacific Biological Station, Nanaimo, B.C., Canada V9R 5K6

14. **Morris, J.F.T., *D.W.* *Welch*, and O.A. Rassadnikov.** 1991. Preliminary results from the 1991 joint USSR-Canadian research cruise to the North-west Pacific Ocean. *(Document submitted to the Annual Meeting of the International North Pacific Fisheries Commission, Tokyo, Japan, November, 1991, 14 p.).* Dept. of Fisheries and Oceans, Pacific Biological Station, Nanaimo, B.C., Canada V9R 5K6

15. ***Welch*, *D.W.*, L. Margolis, M. Henderson, and S. McKinnell.** 1991. Evidence for attacks by the bathypelagic fish *Anotopterus pharao*

(Myctophiformes) on Pacific salmon (*Oncorhynchus spp.*). *(Document submitted to the Annual Meeting of the International North Pacific Fisheries Commission, Tokyo, Japan, November, 1991, 11 p.).* Dept. of Fisheries and Oceans, Pacific Biological Station, Nanaimo, B.C., Canada V9R 5K6

16. ***Welch*, *D.W.*** 1991. Analysis of maturity of white sturgeon populations in the Columbia River Downstream from McNary Dam. Project Number 86-50. *Final Contractor's Report to the Oregon State Dept. of Fish and Wildlife, 17330 S.E. Evelyn St., Clackamas, Oregon, USA 97015.*

17. **McKinnell, S., L. Margolis, *D.W. Welch*, and R.J. Beamish [Chairs]**. 1991. Report for presentation to the United Nations pursuant to resolutions 44/225 and 45/197. 86 p. *(Document submitted to the Scientific Review of North Pacific High Seas Driftnet Fisheries. Sidney, B.C., Canada, June 11-14, 1991).*

18. ***Welch*, *D.W.*** 1992. Possible future high seas salmon research by the Pacific Biological Station. *In: Ishida, Y., K. Nagasawa, **D.W. Welch**, K.M. Myers, and A.P. Shershnev [eds.] Proceedings of the International Workshop on Future Salmon Research in the North Pacific Ocean, Shimizu, Japan.* Special Publication of the National Research Institute of Far Seas Fisheries 20:37-42

19. **Morris, J.F.T., *D.W. Welch*, and O.A. Rassadnikov**. 1992. Data report from the 1990 and 1991 joint USSR-Canada salmon research cruises to the North Pacific Ocean. *Canadian Data Report of Fisheries and Aquatic Sciences No. 891, 175 pages.*

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October, 1992. 6 pages.

23. Morris, J.F.T., *D.W. Welch*, and W. Shaw. 1992. Preliminary results from the Canadian high seas salmon research cruise to the eastern North Pacific Ocean, July 5-23, 1992. *Document submitted to the Annual Meeting of the International North Pacific Fisheries Commission, Seattle, U.S.A.,* October, 1992. 6 pages.

24. *Welch*, *D.W.*, and R.C. Beamesderfer. 1992. Maturation of female white sturgeon in lower Columbia River impoundments. *In: R.C. Beamesderfer and A.A. Nigro, [Eds.] Status and Habitat Requirements of the White Sturgeon Populations in the Columbia River Downstream from McNary Dam. Volume II. p. 89-107. Final Report of Research (Contract DE-AI79-86BP63584) to Bonneville Power Administration, Portland, Oregon.*

25. *Welch*, *D.W.*, K. Shortreed, J. Stockner, J. Hume, K. Morton, and I. Williams. 1993. Recommended Target Escapement Levels for the Horsefly Sockeye Population. *PSARC Working Paper S93-3. 35 p. & 16 Figures.*

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Section Status Report No. SRe 17-94. 6p.

40. **D.J. Blackbourn and *D.W. Welch*.** 1994. 1994 Fraser Sockeye Johnstone Strait Diversion Rate Forecast No. 4. Recruitment Assessment Section Status Report No. SRe 21-94 4 p.

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44. ***Welch*, *D.W.*, and J.F.T. Morris.** 1994. Evidence for Density-Dependent Marine Growth in British Columbia Pink Salmon Populations. Document submitted to the Annual Meeting of the North Pacific Anadromous Fish Commission, Vladivostok, Russia. October, 1994. 33 pages. *NPAFC Document No. 97.*

45. ***Welch*, *D.W.*** 1995. The Effects of Ocean Warming on Distribution of Salmonids in the North Pacific. p.4 *In:* E.A. Black [Ed.] Proceedings of a Workshop on the Effects of Escaped Cultured Fishes. March 17-18, 1994. Nanaimo, B.C. 36 p.

46. ***Welch*, *D.W.*** 1995. Ocean Salmon Production Under a Warming Climate. Univ. Of British Columbia Fisheries Center.

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51. Bugaev, V. F., *D.W.* *Welch*, M. M. Selifonov, L. E. Grachev, and M.J. Sweet. 1996. Influence of the Marine Abundance of Pink (*Oncorhynchus gorbuscha*) and Sockeye Salmon (*O. nerka*) on Growth of Ozernaya River Sockeye. Document submitted to the Annual Meeting of the North Pacific Anadromous Fish Commission, Tokyo, Japan October 1996. *NPAFC Document No. 203.*

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59. *(13 Authors including* ***D.W. Welch****). 1997. Report of the Study Group on Ocean Salmon Tagging Experiments With Data Logging Tags.* ICES Anadromous and Catadromous Fish Committee ICES CM 1997/M: 3, 32 pp.

60. ***D.W. Welch***, J.F.T. Morris, H.R. Carlson, E.V. Farley, B. Van Hardenberg, E.R. Carmack, and A. Münchow. 1997. *Results from the CCGS W.E. Ricker Gulf of Alaska Salmon Survey, March 1997. North Pacific Anadromous Fish Commission Document No. 287. 18 Pages and 3 Figs.*

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62. H.R. Carlson, E.V. Farley, R.E. Haight, K.W. Myers, and ***D.W. Welch.*** *1997. Survey of salmon in the North Pacific Ocean and southern Bering Sea-- Cape Saint Elias to Attu Island July-August 1997. North Pacific Anadromous Fish Commission Document No. 254. 24 Pages and 6 Figs.*

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Associated with the 1989-90 Ocean Climate Shift, and Effects on British Columbia Steelhead (*O. mykiss*) Populations. Pacific Stock Assessment Review Committee (PSARC) Working Paper S97-7.

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69. ***Welch, D.W.,*** B.R. Ward, B.D. Smith, and J.P. Eveson. 1998. Influence of the 1990 Ocean Climate Shift on British Columbia Steelhead (O. mykiss) and Coho (O. kisutch) Populations. North Pac. Anadr. Fish Comm. *Extended Abstract*

70. McKinnell, S.M., C.C. Wood, D.T. Rutherford, K.D. Hyatt, & ***D.W. Welch***. 1998. The collapse of the Rivers Inlet sockeye fishery: the case against a freshwater cause. Technical Report. North Pac. Anadr. Fish Comm. Workshop on Climate Change and Salmon Production. P. 8-10.

71. C.G. Wallace, D.J. Noakes, and ***D.W. Welch.*** 1998. An update on trends in catch of Pacific salmon in Canada. North Pacific Anadromous Fish Commission Doc. No. 317, 8p.

72. ***Welch, D.W***., B.R. Ward, B.D. Smith, and J.P. Eveson. 1998. Influence of the 1990 Ocean Climate Shift on British Columbia Steelhead (Oncorhynchus mykiss) and Coho (O. kisutch) Populations. NPAFC Doc. No. 310. 17 p.

73. *(13 Authors including* ***D.W. Welch****).* 1998. Report of The Study Group On Ocean Salmon Tagging Experiments With Data Logging Tags. ICES CM 1998/Assess:

74. Stocker, M., and ***Welch, D.*** (*1998*). Report of the PSARC Groundfish Subcommittee Meeting November 23-26, 1998 and the Steering Committee Meeting December 16, 1998. *Canadian Stock Assessment Proceedings Series 98/19. 38 p.*

75. ***Welch, D.W.,*** J.P. Eveson, F. Whitney, and J.F.T. Morris. (*1999*). Population status and sustainable production of British Columbia's salmon populations in the 1990s. Pacific Stock Assessment Review Committee, Salmon Subcommittee Working PAPER S99-04. 61 Pages. (Originally submitted as S98-14 to the autumn PSARC meeting, but this meeting was cancelled).

76. Stocker, M., ***D. Welch,*** and R. Conser (*1999*). Report of the Joint Canada-USA Review Group on the Stock Assessment of Coastal Pacific Hake/Whiting Stock off the West Coast of North America, February 17-18, 1999. *Canadian Stock Assessment Proceedings Series 99/03. 12 p.*

77. ***D.W. Welch.*** *1999*. Use of Pacific salmon for monitoring the North Pacific. PICES Annual Report No. 11:37-41.

78. ***Welch, D.,*** and Batten, S. (*1999*). A Plan for Use of the Hardy Continuous Plankton recorder in Monitoring the Subarctic Pacific. PICES Report No. 11:53-54.

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80. ***Welch, D.W.,*** and Batten, S.D. *(1999).* A Continuous Plankton Recorder Monitoring Program for the NE Pacific & Southern Bering Sea. Proposal for application to the North Pacific Marine Research Initiative, April 1999. 16 p.

81. ***Welch, D.W.*** *(1999).* Ocean Monitoring for the Pacific. GLOBEC Int. Newsletter 5(1):5-6.

82. Westerberg, Håkan, Paige Eveson, ***David Welch***, L. Karlsson, and E. Ikonen. 1999. "*Data Storage Tag study of Salmon (Salmo salar) Migration in the Baltic: The performance of tags*". ICES CM 1999/AA:07, 13 p.

83. Wallace, C.G., D.J. Noakes, and ***D.W. Welch***. *1999.* An update on trends in catch of Pacific salmon in Canada. N. Pac. Fish Comm. Doc. No. 431. 8 p.

84. ***Welch, D.W.,*** and Batten, S.D. *(2000). "Climate Change, Global Warming, and the PICES mandate-- The Need for Improved Monitoring"*. PICES Press 8(1):24-27

85. Batten, S. and Welch, D. (2000) "CPR sampling of the North Pacific in 2000". Progress Report for PICES IX.

86. Batten, S. and Welch, D. (2000) *"A Continuous Plankton Recorder Monitoring Program for the NE Pacific and Southern Bering Sea".* Progress Report, November 2000. Contract number UAF 00-0023. 5 p.

I. POPULAR ARTICLES

1. **Welch, *D.W.*** 1991. Baka Damashi Koi: New Jewel of the Aquarium World. Seattle Aquarium World News. October.

2. ***Welch*, *D.W.*, and L. Margolis.** 1992. Slash Marks on Salmon: New Evidence Points to a Deep-Sea Predator. The Westcoast Fisherman 6(11; May):25-29.

3. ***Welch*, *D.W.*, and H.R. Carlson.** 1996. Salmon on the High Seas. New DFO-NMFS Research on Juvenile Salmon. The Westcoast Fisherman Volume 10 (June): 33-36.

4. ***Welch, D.W***. (Contributor). "Sensitivities to Climate Change in Canada". 1999. Natural Resources Canada Brochure cataloguing the likely impacts of global warming on Canadian natural resources. My work features as one of the key examples. (http://sts.gsc.nrcan.gc.ca/adaptation)

5. ***Welch, D.W***. 2001. *"Canada's Ocean Salmon Research and the W.E. Ricker".* Shorelines (DFO Internal Publication). xx pages.

I. OCEANOGRAPHIC & SEA-GOING EXPERIENCE

May 17-23, 1978. Oceanographic surveys, CSS DAWSON. Scotian Shelf & Browns
Feb 8-14, 1978. Bank, Nova Scotia. Standard CTD & chemical oceanographic
Dec 10-17, 1977 survey techniques.
Oct 10-17, 1977

June 10-21, 1985. Groundfish survey, R/V. G.B. REED. Queen Charlotte Islands and Hecate Strait, British Columbia.

4 June - 6 July, 1988. **Canadian Observer**; Joint Canada-Japan High Seas Salmon Research, F/V KANKI MARU NO.3, S.W. of the Aleutian Archipelago.

25 April - 16 May, 1990. **Chief scientist**; Joint USSR-Canada High Seas Salmon Research, R/V TINRO, Eastern North Pacific.

27 February - 23 March, 1992. **Chief scientist**; High Seas Salmon Research cruise to the Eastern North Pacific Ocean, R/V W.E. Ricker Cruise designed to determine distribution and abundance of Pacific salmonids in the Subarctic Domain, and their relationship to physical oceanographic features and biological factors, including diet and ration size. Extensive CTD sampling, collection of Pacific salmon using gill nets and mid-water trawls, sampling for ration size and composition of stomach contents; collection of scale, muscle, and organ samples for stock identification using electrophoretic techniques, scale pattern analysis, isotopic analyses, and energy budgets. This cruise was the first of nine cruises I organized in 1992 to examine the factors controlling the oceanic distribution of Pacific salmon.

25 November - 24 December, 1992. **Co-Chief Scientist**; Japanese-Canadian Trans-Pacific Winter Research Cruise, R/V KAIYO MARU. This cruise was the final cruise of 9 Japanese & Canadian research cruises I organized to examine the physical and biological factors determining the southern limit to the distribution of Pacific salmon in 1992.

23 March - 11 April, 1995. **Chief Scientist**; High Seas Salmon Research cruise to the Eastern North Pacific Ocean, F/V Anita J. Cruise was designed to test a new rope trawl for sampling salmon on the high seas, and to further study the distribution and abundance of Pacific salmonids in the Subarctic Domain in Spring. Extensive CTD sampling, collection of Pacific salmon using mid-water trawls, sampling for ration size and

composition of stomach contents; collection of muscle and organ samples for bioenergetic studies.

27 September - 12 October, 1995. **Chief Scientist**; High Seas Salmon Research cruise to the Eastern North Pacific Ocean, CCGS W.E. Ricker. This was one of two simultaneous research cruises I coordinated with U.S. scientists to compare the performance of the rope trawl developed by my program for sampling salmon on the high seas, and the Bernard-Sigmund beam trawl, and to begin a study on the coastal and offshore migration strategies of juvenile salmon in the fall.

10 March - 7 April, 1997. **Chief Scientist**; High Seas Salmon Research cruise to the Eastern North Pacific Ocean, CCGS W.E. Ricker. This fisheries and oceanographic survey was conducted to establish the offshore migratory pathways of juvenile Pacific salmon, and involved coastal and offshore pelagic sampling with the hexagonal mesh surface rope trawl. Concurrent CTD, ADCP, and nutrient analyses were conducted to measure the intensity of the Alaska Coastal Current in spring, and the extent of potentially nutrient depleted waters in the Gulf of Alaska.

27 May - 10 June, 1998. **Chief Scientist**; Coastal Salmon Research cruise, CCGS W.E. Ricker. This fisheries and oceanographic survey was conducted to begin establishing the cause of the decline in marine survival of salmon in southern regions of the province. Concurrent CTD, ADCP, and nutrient analyses were conducted to measure the intensity of the Alaska Coastal Current in spring, and the extent of potentially nutrient depleted waters in the Gulf of Alaska. The survey extended from Vancouver Island to Baranof Island, SE Alaska.

24 August - 7 September, 1998. **Chief Scientist**; Coastal Salmon Research cruise, CCGS W.E. Ricker. This fisheries and oceanographic survey was conducted to begin establishing the cause of the decline in marine survival of salmon in southern regions of the province. Concurrent CTD, ADCP, and nutrient analyses were conducted to measure the intensity of the Alaska Coastal Current in spring, and the extent of potentially nutrient depleted waters in the Gulf of Alaska. The survey extended from Vancouver Island to Baranof Island, SE Alaska.

17 - 30 May, 1999. **Chief Scientist**; Coastal Salmon Research cruise, CCGS W.E. Ricker. This fisheries and oceanographic survey was conducted to

begin establishing the cause of the decline in marine survival of salmon in southern regions of the province. Concurrent CTD, ADCP, and nutrient analyses were conducted to measure the intensity of the Alaska Coastal Current in spring, and the extent of potentially nutrient depleted waters in the Gulf of Alaska. The survey extended from Vancouver Island to Baranof Island, SE Alaska.

J. TRAINING COURSES

Advanced Training, S-Plus Statistical Programming and Data Analysis Language. Statistical Sciences Inc., Seattle, Washington. April 22-24, 1992. Instruction in advanced techniques for the use of the S-Plus programming language for high level statistical programming, exploratory data analysis, and graphical analysis. Training was conducted on a HP 720 workstation running UNIX v. 8.07 and the MOTIF X-Windows protocol.

Dept. of Fisheries and Oceans, Staff Relations Training for Managers. Management Rights & Limitations; The Discipline Process; The Grievance Process; Interpretation of Collective Agreements; The Canada Labour Code & Work Place Health & Safety. Nov. 16-18, 1993.

Advanced Training, Statistical Models in S-Plus. Statistical Sciences Inc., Nanaimo, B.C. May 1-3, 1994. Instruction in advanced statistical modelling techniques for Linear Models, ANOVA, Generalized Linear Models (GLIM), Generalized Additive Models (GAM), Localized Regression Models (Loess), Tree-Based Models, and Non-Linear Models.

Media Relations Workshop. Coyote Communications Corporation. November 28, 1995. One day workshop involving on-camera interviews and sessions on dealing with the media; What the media needs, differences between print, radio, and television media; strategies for dealing with the media.

Marine Emergency Duties – A1 Training Course. Certificate No. 4380/99. A total of 19½ hours of instruction in basic marine safety issues, covering fire suppression techniques and equipment, use of survival suits, life jackets, and life rafts, plus elementary medical issues resulting from sinkings at sea, and methods of helicopter and ship recovery of survivors. 23-25 Feb. 1999.

Modern Safety Management for Managers and Supervisors. (March 22-25, 1999). Modern techniques for managing and planning for safety in the

workplace; legal responsibilities of the employer; strategies for establishing and maintaining safety in the work environment; methods of dealing with subordinates to promote safe working practices.

K. EXTRAMURAL ACTIVITIES

Nanaimo Japanese Language School. Principal, 1993–2000. Teacher: Advanced Japanese (1994-95); Intermediate Japanese (1995); Advanced Japanese (1996); Intermediate Japanese (1998-2000).

Departure Bay Boy Scouts. Vice-Chairman, 1990-1996.